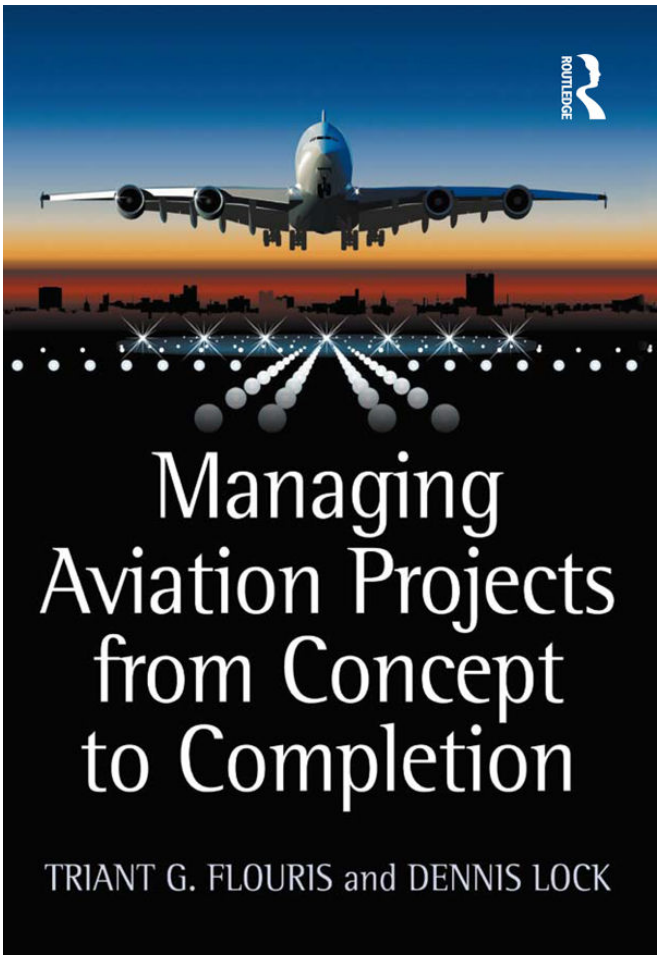


Managing Aviation Projects from Concept to Completion

TRIANT G. FLOURIS and DENNIS LOCK


ROUTLEDGE
Managing
Aviation Projects
from Concept
to Completion
TRIANT G. FLOURIS and DENNIS LOCK

MANAGING AVIATION PROJECTS FROM CONCEPT TO COMPLETION

For Anne
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TRIANT G. FLOURIS

&

DENNIS LOCK

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Foreword

William DeCota
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There once was a time long ago when nature claimed the planet earth. Then humans became the most dominant species the earth had ever known and they managed the flora and fauna, harvested the raw materials and built cities, roads, farms and other infrastructures that supported robust life. But it didn't just occur by happenstance … the best implementation of man's programs, policies and plans occurred because of good project management.

The world as we know it today did not just evolve because of a chance happening of events. It happened because people assembled, they envisioned ways to make life better, and they devised ways to develop and implement those ideas and bring them to reality by mustering resources and delivering them in the best way possible. During prehistoric times, back in the stone age, project management was rough and primitive, but the art of early ritual paintings, literature and the remnants of early societies nonetheless depicts the earliest humans as organized around primitive techniques of project management in the way they constructed gathering places and temporary shelter, roads, crop storage facilities and early versions of what we would know as capital projects today.

Our world has come a long way from the origins and development of early human culture between the first appearance of man as a tool-using mammal about 700,000 years ago, and our society as we know it today. Trillions of dollars are spent in our world on capital projects both by the government, such as roads, railroads, airports, storm and sanitary sewer systems and by the private sector on everything from office buildings to houses, to public utilities to manufacturing plants. Likewise, airports, a concept not imaginable to early humans, were once less than 100 years ago just grassy fields, nothing more than a place for the landing and take-off of planes. There was no order, no development, and no progress. But thanks to careful and thoughtful airport management, larger planes evolved and commercial passenger and cargo business evolved thanks to paved runways, terminal buildings, navigational

aids and customer services. While airports are now complex global business enterprises, they are fundamentally just an infrastructure—places to get people and goods out of land vehicles into air vehicles and vice versa through access systems, roadways and parking lots, terminals, hangars and cargo buildings, runways and airfields and even airspace technologies, systems and procedures.

The breadth of the project management challenge is clear, just looking at the New York region's airports over the past ten years. The Port Authority as the operator of the region's major airports—has invested heavily to increase capacity and meet air travel demand at its airports. Over the past ten years the Port Authority has invested over $15 billion in upgrades in LaGuardia, Newark Liberty and JFK and its latest capital plan includes an additional $6 billion in spending over the next 10 years. This will include runway access improvements, modernizing airfield instruments, and rehabilitation and improvements of taxiways. Anticipating further expansion of the region and air travel demand, in November 2007, the Port Authority took control of the lease for Stewart International Airport in Newburgh, NY and expects to spend hundred of millions to provide a crucial service to help meet the demand for passengers and cargo carriers. Further, the Port Authority has implemented a comprehensive Delay Reduction Program, earmarking millions of dollars, to accelerate capital projects that can reduce delays. These initiatives will increase operational flexibility on the airfield by creating capacity for simultaneous operations on three runways and reducing queuing times on taxiways.

On the federal level, the Federal Aviation Administration (FAA) is moving forward with the Airspace Redesign Program, first proposed in 2005, which is intended to improve New York-New Jersey airports capacity. This program will consolidate several sectors of airspace under one Air Route Traffic Control Center in the New York/New Jersey/Philadelphia area. Also, in February 2009, the FAA announced its long anticipated NextGen program, which will use satellite-based technologies across U.S. aviation for the first time, an important advance in technology that will provide significant improvements to efficient air traffic movement over time.

Over the next 10 years alone, airports are estimated to spend almost $100 million on capital investments. Devising these projects requires thoughtful vision; to ensure timely, cost effective and efficient project delivery requires the resources and techniques necessary to manage and implement them.

Whether it's an airport, government or any other organization, to be successful, the organization must provide overall leadership, responsibility and accountability for the advancement and successful accomplishment of projects in accordance with world-class professional project management standards and measures, through the efforts of staff that possess the authority, systems and skills necessary to take projects from initiation through to construction, on time and within budget. Business plans define an organization's mission, objectives, goals and strategies. Then actions are evaluated that can fulfill those strategies and meet those goals and objectives in fulfillment of the mission.

Because airports are capital intensive, many have created project management departments that manage and implement projects by providing the project management resources and techniques necessary to ensure timely, cost-effective and efficient project delivery. These departments provide overall leadership, responsibility and accountability for the advancement and successful accomplishment of projects in accordance with world-class professional project management standards and practices, through the efforts of staff that possess the authority, systems and skills necessary to take projects from initial design stages through construction, on time and within budget. Project management begins with an organization's core business needs for asset development and asset management. It establishes clear authority, responsibility and accountability for delivery of projects. It develops project management systems and performance metrics to ensure consistent accomplishment of project requirements. It requires accountability to ensure a work climate where employee responsibilities and deliverables are properly communicated and understood by all parties.

Successfully *managing aviation projects from concept to completion* requires thoughtful structure, training, staff development and techniques. A standardized project methodology and centralized reporting systems are especially necessary so all people and systems can speak a common language in a multiple project enterprise environment. As airports continue to grow in complexity, as technology like electronic kiosks replace civil engineering projects like ticket counters for the processing of people and goods, so too will project management grow in sophistication. Triant Flouris and Dennis Lock have thoughtfully documented the steps to be followed for the development and implementation of a project and have provided students with a common road map to successful project completion and

implementation, recognizing that as project's life cycle begins with an idea and continues long after it is built. Their textbook on project management is not only useful today but is sure to endure in every era.

Foreword

Dr Yiannis Paraschis
CHIEF EXECUTIVE OFFICER
ATHENS INTERNATIONAL AIRPORT S.A., GREECE.

As I am writing this, our industry is facing its worst economic crisis since the introduction of commercial jet services, with disastrous passenger and cargo volumes buffeting in their vortices our future outlook and plans. If the aftermath of the September 11, 2001 events in the United States was not sufficiently challenging, our times have further highlighted the need for clear strategic thinking based on sound management principles. We also need a calm and composed approach to short- and mid-term issues and we need to have solutions that we perfectly execute. The adventures that new aircraft developments have faced in the recent past, exposing management weaknesses and frustrating shareholders and customers alike, have stressed that project management remains a vital instrument to develop ideas and concepts, and to turn them into products and services that appeal to today's travelers and will care for the future travelers' needs.

Our industry's development is marked by successful projects. The new Athens airport, Europe's first public-private partnership for a greenfield airport development, is such a successful case. What was initially an idea for a solution – the Greek government needed to obtain an airport worthy of the city – has become a motor of the national economy, and an exemplary airport operator as evidenced by global industry rankings and reports.

Athens International Airport Company was founded in 1996. Using, among others, state of the art project management tools, we simultaneously oversaw the construction of the new Athens airport, and amalgamated into a team that was in time ready to assume the complex role of a commercial airport operator. Operations started in March 2001, only 56 months after construction was launched. The project was on time and on budget.

Immediately the new airport company turned its attention to Athens' and Greece's seminal event of the 2004 Olympic and Paralympic Games. We prepared a range of plans to not only handle the special demands of the Olympic and Paralympic families, but to also ensure that passengers and

visitors would experience the most pleasant stay at our airport. To support our planning we set specific milestones and integrated them into a realistic schedule. To ensure that necessary resources were available our entire organization once again drew on its project skills and formed a team of highly competent people capable of making the right decisions at the right time under the pressure of the event's magnitude.

These two major project successes, the quality of our operations as well as our financial results in recent years have put Athens on the map as one of the high performers among the worlds' airports.

When I was asked to write the foreword to this book, I was surprised to find that we as an industry do not have a reference document that gathers all the available knowledge and expresses what our industry has been instinctively accomplishing since its very birth. I am happy that this oversight has now been corrected.

This book, *Managing Aviation Projects from Concept to Completion*, with its all-encompassing content and clear examples will help aspiring students understand all facets of aviation project management and will be a useful reference tool for experienced project managers.

Preface

Project management has been a rapidly expanding branch of management for over 60 years, and its growth seems to grow unabated. This is apparent from the number of courses offered by many respected business schools and by the continual expansion of membership lists in professional associations (not least of which is the Project Management Institute). Coupled with this expansion has been the recognition of project management as a profession in its own right, complete with its range of qualifications to which people can aspire and which, when acquired, add a degree of confidence to companies needing the services of competent project managers. Thus we should expect to see a corresponding record of success in all projects, public and commercial, yet still far too many fail, some in spectacular fashion.

Underlying all successful projects is adherence to proven project management concepts and practices. Project management demands above all the application of logic and commonsense. Stripping away the jargon, this means ensuring that every project is clearly defined in scope, launched against a sound business plan, and planned and controlled with determination so that the set objectives are kept in mind from the beginning and achieved at the end.

The aviation industry is home to many projects worldwide, ranging in scope from small projects to those which require the partnership of several major companies. No other industry has a more diverse range of project types, which cover everything from the design and manufacture of aircraft and their components, through the establishment or renewal of services such as air traffic management technology, processes and systems, the establishment of airlines and all their support services, and the provision of air services and design and renovation of airports. Furthermore, its intense focus on safety as well its unique regulatory structure renders Aviation a unique industry.

Project management books abound but, until our previous book *Aviation Project Management*, none of these publications expressed specifically the

needs of aviation project managers. The immediate success of that first book clearly indicated its need, and has led to this new volume on the same subject. Here, we again explain proven methods that have achieved success in projects throughout a wide range of industries and will do the same for aviation projects. We have used case examples based on aviation throughout to illustrate best practice in aviation project management. However, in this book we have taken more space in which to develop and explain every topic, so that even advanced students and practicing project managers in the aviation industry and beyond should benefit from having it on their shelves.

Triant G. Flouris and Dennis Lock
Nashua, NH, USA St Albans, UK

1
The Nature of Projects and their Management

Every significant project involves the conversion of an initial concept or dream into a final result that is expected to satisfy the hopes and wishes of the project owner. In business projects (including aviation projects) these hopes and wishes will undoubtedly include the realization of strategic, financial and operational benefits. But an ever-present element of risk and uncertainty means that the path leading to completion can never be forecast with absolute accuracy. There have been, and continue to be, far too many examples of projects that go disastrously wrong, perhaps causing the planned opening of new routes to be postponed or aborted, or meaning that new aircraft are delivered years late to the airline operators impatiently waiting to put them in service.

Some project failures cause serious inconvenience to passengers and financial loss to the relevant airline. The disastrous opening of Terminal 5 at London Heathrow in March 2008 is such a case, where many British Airways flights had to be cancelled, stranding irate passengers for days and separating them for weeks from 15 000 pieces of baggage, all principally because the new state-of-the-art baggage handling system failed to perform as intended. There are many other examples of aviation project failures, but there have also been remarkable success stories. For example, Hong Kong International Airport opened on time on 6 July 1998 in spite of all the risks and the large number of different companies involved (over 20 000 workers from 30 countries took part in the project).

Of course no project will succeed if the design engineers (whether for hardware or IT software) are not fully competent and adequately directed. But many failures (and conversely the success of projects such as Hong Kong International Airport) owe their bad or good fortunes to the quality of their project management methods and to their project managers.

AN INTRODUCTION TO PROJECT MANAGEMENT

The purpose of project management is to visualize all the activities that lie along the path to successful project completion, and then to plan, organize and control those activities so that the project is completed successfully in spite of many hazards and risks. The primary aim of the project manager is for the end result to satisfy the project sponsor or purchaser and all the other principal stakeholders, within the promised timescale and without using more money or other resources than those that were originally set aside or budgeted.

Projects before 1900 were generally managed by the creative architects and engineers themselves—people such as Sir Christopher Wren (1632–1723), Thomas Telford (1757–1834) and Isambard Kingdom Brunel (1806–59). There was no separately recognized profession of project management. Commonsense, extreme determination and dedication (often at the expense of neglecting personal health) usually got the job done. The time had not yet come for the industrial engineers and behavioral scientists who would eventually study working practices, organization theory and people at work.

Rapid industrialization and the demands of munitions production in World War 1 saw the emergence of management scientists and industrial engineers such as Elton Mayo and Frederick Winslow Taylor, who studied people and productivity in factories (see, for example, Kanigel, 1997). Henry Ford made production line manufacture famous with his Model T automobile and, especially important for project managers, Henry Gantt (1861–1919), who worked for Taylor, developed his now-famous bar charts which are still popular and used universally today. (For a comprehensive account of the historical development of project management see Morris, 1994).

Now project management has become a well-established profession in its own right. Most professions have their own associations and project management is represented in most countries of the world by at least one organization. By far the largest of these organizations worldwide is the global Project Management Institute (PMI), which has its headquarters in Newtown Square, PA. <http://www.pmi.org>.

FOUR DIFFERENT TYPES OF PROJECTS

The principal identifying characteristic of any project is its novelty. It is a step into the unknown, fraught with risk and uncertainty. No two projects are ever exactly alike: even a repeated project will differ from its predecessor in one or more commercial, administrative or physical aspects. However, we have found it possible and convenient to group all projects into four different generic types, all of which occur in the aviation industry. Each of these will now be outlined, but many aviation projects are so complex that they comprise a combination of sub-projects from two, three or all of these four types.

Type 1 Projects: Civil Engineering and Construction

Outside the aviation industry this classification also includes petrochemical, mining and quarrying projects. Type 1 projects are those which spring most readily to mind whenever industrial projects are mentioned. A common feature is that the actual work (the project implementation, execution or fulfilment phase) must be conducted on a site that is exposed to the elements, usually at some considerable distance from the main contractor's head office. As such these projects are often open to the public gaze, and made obvious by the presence of heavy machinery or tower cranes.

These projects incur special risks and problems of organization. They often require massive capital investment, and they deserve (but do not always get) rigorous management of progress, finance and quality. Many operations are hazardous so that health and safety aspects demand special attention, particularly in heavy work such as construction and tunneling.

For very large industrial projects the funding and resources needed can be too great for one contractor to risk or even find. The organization and communications are therefore likely to be complicated by the participation of many different specialists and contractors, possibly with the main players acting together through a consortium or joint venture company established specifically for the project.

Aviation projects in this category are principally concerned with the development or improvement of airports, but all aviation companies that occupy offices or industrial premises can be involved at one time or another in construction projects when they build, enlarge or adapt their business premises.

Type 2 Projects: Manufacturing

Manufacturing projects result in a piece of mechanical or electronic equipment, a machine, ship, aircraft, land vehicle, or some other product or item of specially designed hardware. The finished product might be purpose-built for a single customer but internal research and development (R&D) projects for products to be sold in all market sectors also fall into this manufacturing category. Products can range from micro-miniature objects to giant assemblies such as machines, trucks and ships.

By far the most obvious aviation projects in this category are those for the design and manufacture of aircraft, but practically all aviation projects need manufactured components and systems. Thus all sectors of the aviation industry depend to a lesser or greater extent on manufactured products or systems.

Manufacturing projects are usually conducted in a laboratory, factory or other enclosed environment, where the company should more easily be able to exercise on-the-spot management and provide an optimum environment in which to perform and manage the work. Of course, these ideal conditions do not always apply. Some manufacturing projects involve work away from the home base, for example in installing and commissioning a machine or equipment at an airport, customer training and post-project service and maintenance.

More difficult is the case of a complex product that is developed and manufactured by a consortium of companies, sometimes with members based in different countries. A common example is aircraft design and production, where the engines might be developed and manufactured in one country, the wings in another, and the final assembly taking place in a third country. Such international manufacturing projects are prone to higher risk and difficulties in control and coordination arising through organizational complexity, national rivalries, contract disputes, long-distance communications, multiple languages and conflicting technical standards. The longest production delays in the Airbus A380 project have been attributed to the use of different software standards in two participating companies (although both these companies used the same design software, they reportedly employed different versions of that software, so that cable looms designed and delivered by one company did not match the aircraft connection points provided by the other).

Type 3 Projects: Projects Associated with Management Change and New IT Systems

This class of project proves the point that every company, whatever its size, can expect to need project management expertise at least once in its lifetime. These are the projects that arise when companies relocate their headquarters, develop and introduce a new computer system, launch a marketing campaign, prepare for a trade exhibition, produce a feasibility or other study report, restructure the organization, mount a stage show, or generally engage in any operation that involves the management and coordination of activities to produce an end result that is not identifiable principally as an item of hardware or construction. An airline that decides to launch a regular service between new destinations is primarily embarking on a Type 3 project.

Not all projects are conducted commercially or for profit. Most not-for-profit organizations, including national and local government departments, professional associations, charities and disaster relief agencies, conduct projects that fall into this category of management projects.

Although management projects do not usually result in a visible, tangible creation such as a piece of hardware, much often depends on their successful outcome and they can require enormous investment. There are many well-known disaster cases, both within and outside aviation, where failure to implement a new computer system correctly has caused a government department or a commercial company financial loss and public condemnation. In aviation, one example among many is in air traffic control, where failure of a new system to operate as expected has caused serious operational disruption, exposing the managers responsible to public discredit and passengers to the misery of flight delays and cancellations. Effective project management is at least as important for these Type 3 management projects as it is for the largest construction or manufacturing project.

Type 3 projects may be associated with or even depend upon Type 1 or Type 2 projects. For example, if a company decides to relocate to a new, purpose-built office, the overall relocation project is itself a Type 3 management project but its success will depend also on the Type 1 project for constructing the new building. Thus projects of different types may be directly associated with each other in a company's current program of projects or project portfolio.

Type 4 Projects: Projects for Pure Scientific Research

Pure scientific research projects are truly a special case. They occasionally result in dramatically profitable discoveries, perhaps in new drugs or materials with greatly improved physical properties (allowing, for example, the use of carbon fiber technology in aircraft construction to provide greater strength with less weight). On the other hand, pure research projects can consume vast amounts of money, yet yield no practical or economic result. Thus pure scientific research projects carry very high risk because they attempt to extend the boundaries of current human knowledge. The objectives of these projects are often difficult or impossible to define and there may be little or no expectation of the eventual outcome.

Note that these pure scientific research projects are not to be confused with R&D projects. R&D work usually has a more well-defined or specific objective, such as the development of a new product, the specification for which has been predetermined and is a required deliverable of the project. Thus R&D projects are usually Type 2 or Type 3 projects and can therefore be subjected to regular project management methods.

Pure research projects, because they are so difficult to define and plan, are not usually amenable to the project management methods that can be applied to industrial, manufacturing or management change projects. However, some form of control must be applied. Money and other resources cannot be spent without any form of monitoring or restraint. Budgets have to be set so that expenditure is limited within available funding.

A sensible method for controlling a pure scientific research project is to conduct regular management reviews (perhaps every three months), at each of which the progress can be assessed and the potential value of the project is evaluated afresh. At any one of these reviews a management decision can be taken either to stop the project (known colloquially as pulling the plug) or to release a new tranche of funds to allow the research to continue at least until the next review. Although this can be very unsettling for the scientists and technologists involved (who thus never know what the future holds for them) the project sponsor is not committed to pouring money for ever into a vast welcoming hole. This procedure, where continued project funding is dependent upon the outcome of periodic reviews, is known as stage-gate control.

Although pure research activities might themselves lie outside the scope of familiar project management methods, the provision of accommodation, communications, equipment and research materials might well constitute Type 1, 2 or 3 capital investment projects to which effective project management can and must be applied.

PROJECT LIFE CYCLES AND LIFE HISTORIES

Some projects come into being gradually, and others fade out slowly, so that their precise beginning and end dates can be difficult to recognize. However, most projects have not only actual beginning and end dates but also several significant intermediate dates during their progress that can be recognized as key events or 'milestones'. The period between the beginning and end of any project is usually referred to as the project life cycle.

A Simple View of a Project Life Cycle

Consider, first, the typical life cycle of small projects. We define a small project here as one that would normally have:

- fairly short duration;
- modest expenditure;
- easily defined tasks that are relatively straightforward to manage.

Most authorities and writers, when they talk about the life cycle of a project, refer to the period that begins with the authorization of work on the project (or the signing of a customer-contractor contract) and ends with the handover of the desired product to the customer. This view can often be too simplistic, but it is the part of these projects that is of most concern to their project managers. Figure 1.1 clearly shows that the activities which take place during this period do indeed form a true project cycle, because they begin and end with the customer.

Traveling clockwise round the cycle reveals a number of steps or *phases*, each of which is represented by a circle in the diagram. The boundaries between these phases are usually blurred in practice, because the phases tend to overlap. For example, some project purchasing and fulfilment work can usually start before well before design is complete.

This view of a project life cycle is, in very many cases, too elementary because it ignores everything that must happen before actual work can start. It also takes no account of what happens to the project after its delivery to the customer. For a more complete picture, we really have to consider not only the project life cycle as seen by the project manager, but also the entire life history of the project from its conception to death and final disposal.

A More Comprehensive View of a Project Life Cycle or History

The life cycle shown in Figure 1.1 holds good for small, relatively simple projects but for most capital projects many more phases can usually be identified. For example, the six phases of Figure 1.1 have grown to 15 separately identifiable phases in Figure 1.2, which represents the life history of a fairly large capital project. Projects differ so greatly that there is no such thing as a typical life history pattern but the sequence in Figure 1.2 is broadly applicable to capital aviation projects that involve many stakeholders and public interests (stakeholders are identified, explained and discussed in Chapter 2).

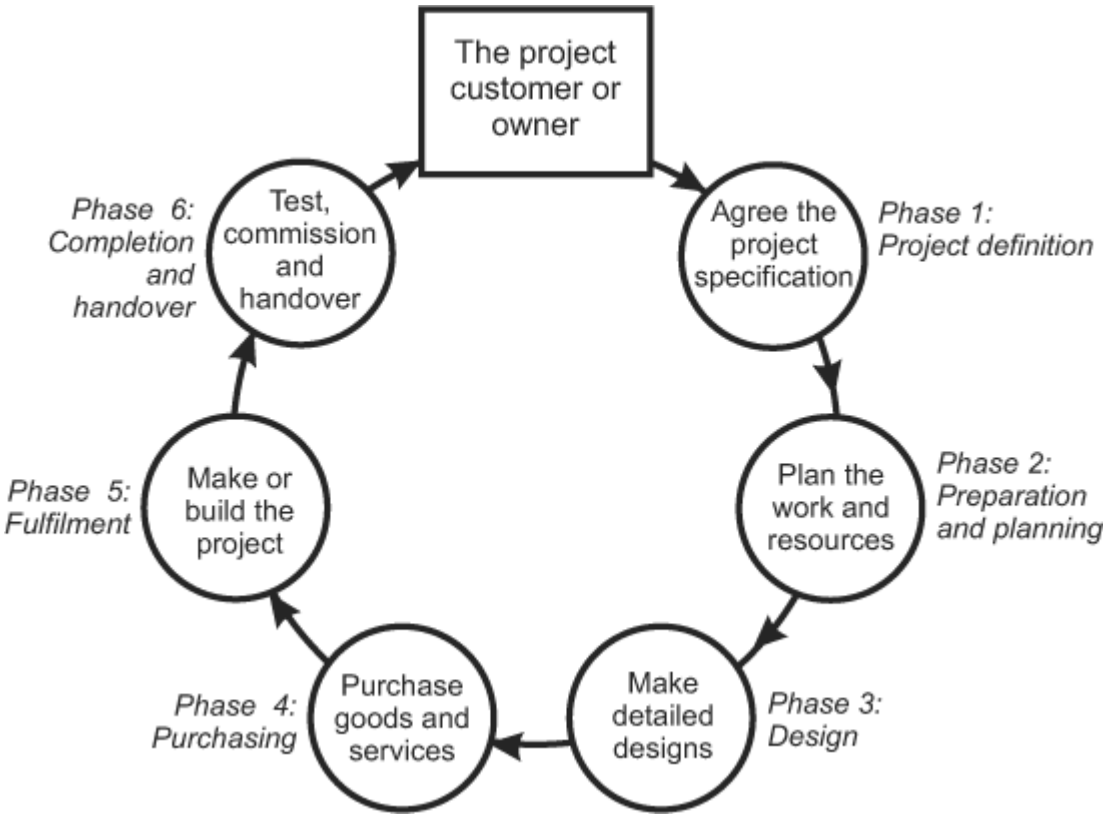

The project customer or owner
Agree the project specification
Phase 1: Project definition
Plan the work and resources
Phase 2: Preparation and planning
Make detailed designs
Phase 3: Design
Purchase goods and services
Phase 4: Purchasing
Make or build the project
Phase 5: Fulfilment
Test, commission and handover
Phase 6: Completion and handover

Figure 1.1 A simple view of a project life cycle

Explanation of the life history phases The upper portion of Figure 1.2 is a bar chart that sets out the phases of a large capital project against its total life history timescale. In this case, the full period spanned by the project is about 27.5 years, but remember that this is only an example: actual cases might be anything from one or two years to several decades.

All projects begin as a concept, a gleam in the eye of their progenitor. An entrepreneur or organization recognizes the need for a project and forms an initial idea that justifies further investigation. Phases 1 to 4 comprise this formative period, which should end in proposals and a business plan that describes the project, sets out the financial requirements, and forecasts the intended benefits and the principal milestones. Taken together, these early phases form the initial project definition.

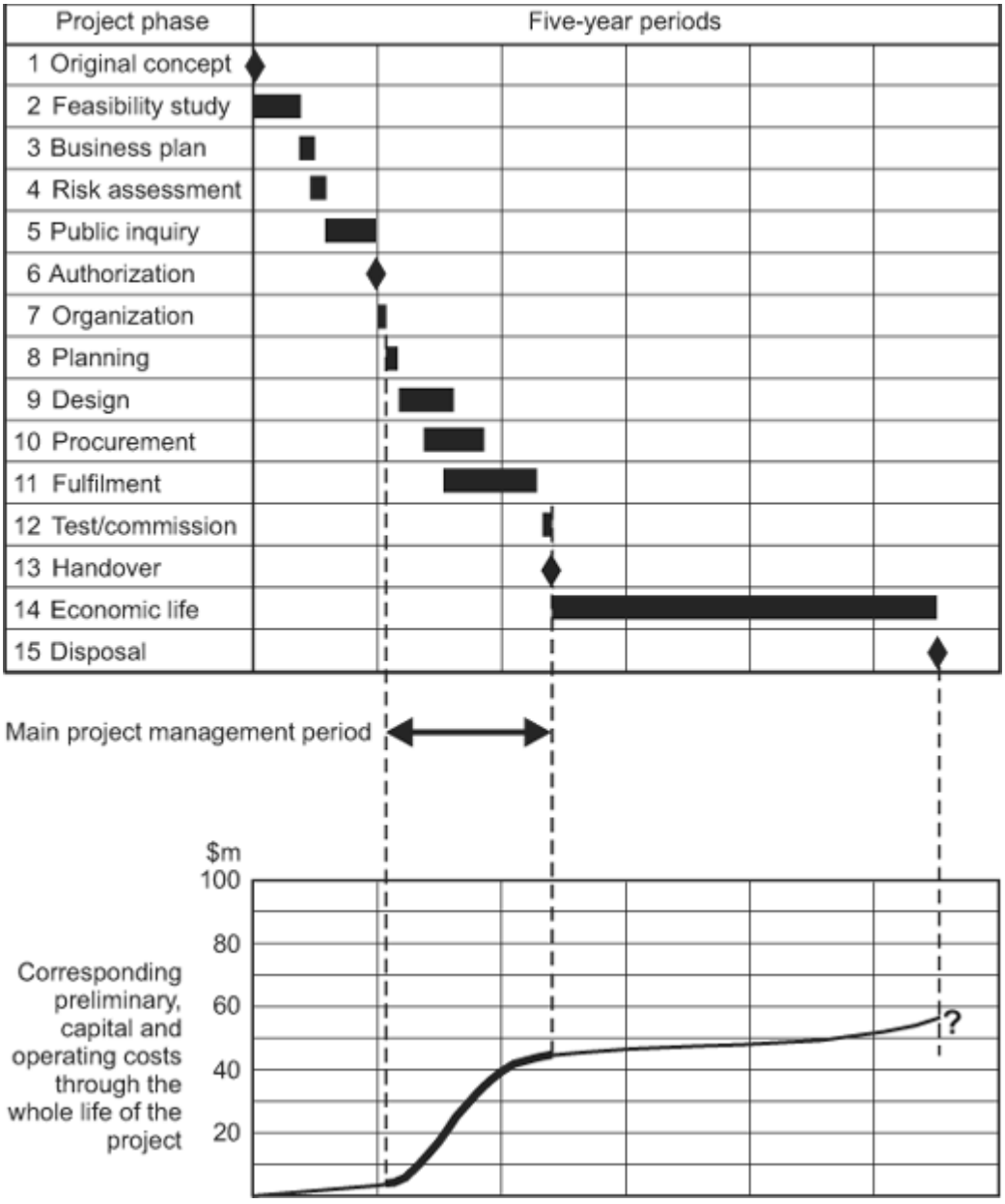


Figure 1.2 A more comprehensive view of a capital project's life history

Projects in the public eye, or which have significant potential environmental or social impact (such as airport development projects) might have to be subjected to one or more public inquiries and prolonged planning applications (Phase 5), which can seriously delay or even prevent the start of the actual project. Many aviation projects are also subject to approval at one, some or all stages by one or more regulatory bodies.

Once everyone has agreed the project definition, all permissions have been granted, and the funds are available, the project can be authorized

(Phase 6). Authorization should really be almost an instantaneous event or milestone rather than a time-consuming phase, but some organizations are very cautious about this process and can drag their feet for several months before agreeing to release the funds and other resources required for the project to start. In fact, we have known cases where authorization has taken so long that, by the time the project started, some aspects of the business plan had become outdated and the project should really have been reassessed for authorization.

When the project has been authorized, the organization has to be put in place. This is Phase 7 in our example and, together with Phase 8, constitutes the project start-up period. Phase 7 usually includes the appointment of the project manager and the setting aside or provision of office space, other accommodation and facilities that will be needed by the project workers. Only then can real work on the project start, which is signaled by the project manager arranging for detailed planning and mobilization of the workforce (Phase 8). Some people recommend taking the less common course of choosing the intended project manager far earlier in the life cycle, so that their valuable practical experience can be exploited in helping to define the project and the strategy for its execution.

Phases 9, 10 and 11 cover the overlapping periods of design, procurement, manufacturing, and assembly or construction, For Type 3 projects, this period would accommodate the management change tasks. Type 1 and 2 projects are finished when they are handed over to the customer to be put into operational use (Phase 13) but this cannot usually be done before the contractor has carried out commissioning and tests or trials (Phase 12) to ensure that the project will be fit for its intended purpose. Type 3 (management change) projects usually require an extended implementation period after initial project completion, during which the new systems, procedures or other company changes are proved and all the affected staff come to accept and perform the new tasks or responsibilities assigned to them. Only then can the full benefits of the project be realized.

Many project management publications limit their account of the project life cycle or life history to Phases 6 through 13. The good reason for this is that these are the phases that most directly come under the control of the project manager, who might not come on to the scene until Phase 6 or 7. These Phases 6 through 13 constitute the most active or fulfillment period of

the project life history and they can be compared loosely with the shorter life cycle concept shown in Figure 1.1.

Another glance at Figure 1.2 shows that our version of the project life history not only begins much earlier than some published versions, but also does not finish until very much later, when the outcome of the original project has come to the end of its useful economic life and is scrapped or otherwise disposed of.

Expenditure Patterns in Relation to the Project Life History

The graph in the lower portion of Figure 1.2 sets out a pattern of expenditure that might be expected throughout the life history of a project. It is drawn on the same timescale as the bar chart and indicates general patterns of expenditure rather than actual monetary levels (because total costs vary so greatly between different projects).

Some expenditure must be made by the project owner or sponsor during the formative, definition phases. In our example we have shown this expenditure to be at a modest level, but some projects require considerable investigation before they can actually start. A feasibility study costing many millions of dollars might sometimes have to be commissioned to explore the risks, benefits and best strategy for the proposed project. Public inquiries and wrangling by different stakeholders over the specification can delay the project start and soak up yet more money (even to the extent that the entire project budget is spent before any work starts, so that refunding has to be arranged). Some large projects might be preceded by pilot projects that themselves demand substantial investment.

The portion of the expenditure curve drawn with a bold line corresponds to the project fulfillment period when the project manager is most actively involved. Almost all the money spent during this time should be built into the real project, to add not only cost to the project, but value. This is one area of the life history where we can be reasonably confident that the pattern will be similar from one project to the next. Expenditure usually builds up very slowly as people are gradually assigned to work on the project, with only a relatively few staff involved in the early stages to carry out initial design and planning.

Later, as working drawings or specifications begin to emerge from the designers or technologists, money has to be committed to buy materials and

equipment so that the main workforce can be engaged to use these purchases to fulfill the project. Nearer the end of the fulfillment phase (Phase 11 in our example) most purchasing costs are over, and people begin to leave the workforce, so that the rate of expenditure falls. This expenditure pattern is typical of most projects and is commonly known as the S-curve. It is the time when the project manager has most direct influence over control of the project's capital costs.

Phase 14 marks the end of expenditure on the project's capital cost and the project moves into a completely different mode. This is the useful operating life of the project, when all the expenditure involved is incurred by the project customer (the project owner) in operating, maintenance, repairs and consumable materials. This is the period, for example, during which a building can be occupied, an IT system remains accurate and efficient or a particular aircraft remains in regular operational service.

When the project nears the end of its economic life, either the owner has no further use for it or the costs of operating, maintenance and repair begin to rise to uneconomic proportions. In aircraft projects this time can be indefinite, because one airline might sell part of its fleet on to other airlines that cannot afford the high investment needed to buy brand new aircraft. In the case of a building the disposal time might happen centuries after it was originally built, with ownership being transferred many times before disposal (demolition) as different occupants come and go. On the other hand, a modern high-technology project might be rendered obsolete after only a few years of successful operation. In some cases the redundant project can be sold on to a third party for scrap, yielding a small cash inflow. At the other extreme, disposal costs for projects involving nuclear materials (such as power generating plants or nuclear weapons) can greatly exceed the original project costs owing to difficulties in handling and storing materials that will remain dangerously radioactive for hundreds of years.

For all these reasons, we have shown a question mark at the end of the project life history costs, because the disposal costs (or cash returns) are so very different from one project to the next.

FOUR PRINCIPAL PLAYERS IN A PROJECT LIFE CYCLE

In Chapter 2 we shall introduce many different project stakeholders but it is convenient and necessary here to introduce four key players in the project life cycle. These are:

1. *Customer* the person or organization for which the project is initially being conducted. We have also used the terms client and project owner in this context, although these are not always true synonyms. The project customer is traditionally a person or organization that pays another organization money in return for a project. However, in many management change projects the company is, in effect, both the customer and its own contractor, with the board or senior corporate management of the company acting as the customer, whilst the internal manager or department instructed to carry out the project assumes the role of contractor. Such complexities can be disregarded for the moment: organization patterns and roles will be discussed more exhaustively later in Chapters 8 and 9.
2. *Contractor* the organization that is principally responsible for executing the project work to the customer's requirements. We have not restricted this term to its more common use in the contracting industry for construction projects. So, again purely for convenience, we use the term contractor in our text to describe any organization or group that carries out a project, whether or not the project is carried out against a formal contract. We use this term, for example, in the context of manufacturing projects, for projects in the not-for-profit sector and for management change projects.
3. *End-user* the individual or organization that will ultimately own and operate the project. This is not always the same person or organization that paid for the original project. For example, an airline that buys or leases one or more aircraft, although it might be regarded as a customer, is also the end-user of the aircraft manufacturing project.
4. *Project manager* a person or company employed by the contractor (or occasionally by the customer) to plan and manage all the project activities so that the project is finished on time, within budget and in accordance with its specification.

Projects are very diverse in their natures and the common notion that every project is carried out by one organization or contractor for one customer is really too simplistic (especially in many aviation projects).

PROJECT MANAGEMENT—A MATTER OF COMMON SENSE, LOGICAL REASONING AND DETERMINATION

All professions have their own terminology, methodologies and procedures. Many of the apparent mysteries of project management will be visited and explained in this book. However, much of good project management is based on sound commonsense and logical reasoning. The project manager must of course have the drive and determination to succeed, but determination alone is not enough. Project success usually depends on the project manager mobilizing brainpower and logical reasoning to plan and progress the project through a sequence of well-defined phases. Project tasks, from concept to completion, have to be planned to take place in their most logical sequence. It is not by accident that the word 'logic' appears several times in our pages.

We have outlined typical project phase sequences and life cycles in this chapter, but the fundamental management requirements are that the project is defined as accurately and fully as possible before any investment is authorized, that the wishes of all stakeholders are clearly understood, an appropriate organization is put in place with adequate resources, and that the project is planned and progressed to completion with determination, good design, and with all but the most essential changes resisted.

SENIOR MANAGEMENT SUPPORT

Even the most promising project will fail if its project manager and the wider project functions are not supported both mentally and materially by the senior corporate management. It is those senior managers who must provide the resources and set up the project organization. It is they who must back up the project manager should disputes require resolution, or if pressure has to be brought to bear on suppliers or participating organizations. No project manager can succeed without the unequivocal support of their superiors.

Harold Kerzner (2000) conducted a fascinating study of the success or otherwise of project management implementation in a wide range of companies. He conducted his initial research rather in the manner of a student working for a dissertation or thesis, and he told one of us that he obtained very good feedback from many of the companies that he approached. In many cases Kerzner was able to report the establishment and maintenance of a good internal project management culture from which the relevant companies

gained long-term operational benefits. But he gives one heartbreaking account of a determined and highly competent woman who, over several years, established a project management support group and company-wide project management culture that began achieving considerable project successes, only to see her project support team and its associated project management culture swept away overnight when a new, short-sighted senior management team took over the company and considered project management to be an irrelevant overhead expense.

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2
Factors for Project Success or Failure

The manager of a typical aviation project would consider his or her task well done if the project finished on time, within its budgeted cost and satisfying the specified description or performance. These three objectives (time, cost and performance) are traditionally the basic parameters for measuring project success or failure and they will be discussed at some length later in this chapter. However, although these three properties are very important, they relate particularly to the execution or fulfillment stage of a project, which is the period of most direct interest to the project manager and the principal contractor.

Other people (not least the customer) might have quite different views about the ultimate success or failure of a project. A project that is delivered on time, within budget and in line with its specification might provide the main contractor (and its shareholders) with a good profit, beneficial publicity and a warm glow of satisfaction but the customer or other end-user who subsequently discovers that the project fails to live up to its initial promise and does not deliver its expected return on investment will perceive the result as a failure. We shall explain later in this chapter that the converse of this can be true, namely that a project which fails to achieve the three primary objectives for the project manager and ruins its main contractor can sometimes blossom later, to realize good benefits eventually for the project owner.

It is apparent, therefore, that when questioning whether or not a project has been successful, the answer can depend upon which of the many stakeholders is asked for the answer. Further, different answers can sometimes be obtained at different phases in the project's life cycle.

The upper portion of Figure 2.1 repeats the bar chart view of a project life history first shown in Figure 1.2. But now the project life is compared not with rates of expenditure, but with some factors that can determine actual or perceived success or failure as the project life history unfolds.

SUCCESS OR FAILURE FACTORS IN RELATION TO THE INITIAL PROJECT DEFINITION

Initial project definition leads to the proposal or business case on which the decision to authorize or disallow the project start will principally depend. This initial definition takes place during Phases 1 to 6 in the bar chart of Figure 2.1. This is clearly too early for anyone to measure the success or failure of the project but it is the time in the project's life history when the foundations for success or failure are laid. The following list identifies some of the shortcomings during this early period that can condemn a project to failure:

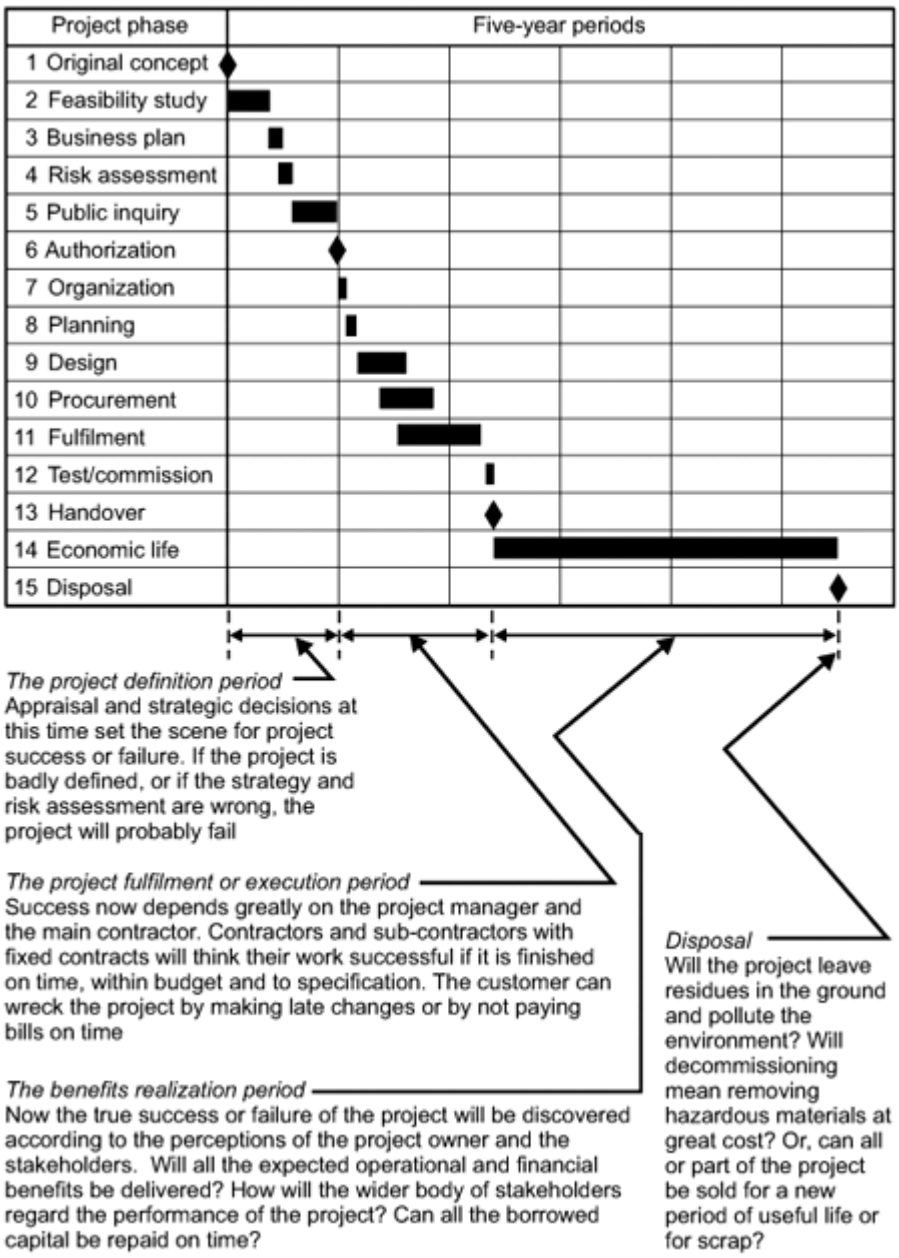

Project phase
Five-year periods
1 Original concept
2 Feasibility study
3 Business plan
4 Risk assessment
5 Public inquiry
6 Authorization
7 Organization
8 Planning
9 Design
10 Procurement
11 Fulfilment
12 Test/commission
13 Handover
14 Economic life
15 Disposal
The project definition period
Appraisal and strategic decisions at this time set the scene for project success or failure. If the project is badly defined, or if the strategy and risk assessment are wrong, the project will probably fail
The project fulfilment or execution period
Success now depends greatly on the project manager and the main contractor. Contractors and sub-contractors with fixed contracts will think their work successful if it is finished on time, within budget and to specification. The customer can wreck the project by making late changes or by not paying bills on time
The benefits realization period
Now the true success or failure of the project will be discovered according to the perceptions of the project owner and the stakeholders. Will all the expected operational and financial benefits be delivered? How will the wider body of stakeholders regard the performance of the project? Can all the borrowed capital be repaid on time?
Disposal
Will the project leave residues in the ground and pollute the environment? Will decommissioning mean removing hazardous materials at great cost? Or, can all or part of the project be sold for a new period of useful life or for scrap?

Figure 2.1 Some perceptions of success or failure during a project's life history

- The project scope (the extent of work required) is not clearly stated and understood.
- The technical requirements are vague.
- The technical expectations are too ambitious.
- Estimates of the cost, the timescale or the expected benefits are too optimistic.
- Risk assessment is incomplete or flawed.

- The intended project strategy is inappropriate.
- Insufficient regard is paid to forecasting cash flows and the timely provision of funds.
- The funds required cannot be made available.
- There are insufficient resources in the organization to carry out the project.
- The interests and concerns of all stakeholders are not taken into account.
- Too little regard has been paid to the motivation and behavior of the people who will execute the project.
- The project manager is not sufficiently experienced or is generally incompetent.
- Particularly in management change projects, insufficient thought is given to how all the managers and workpeople affected by the project will adapt to the changes expected from them.
- Approval to proceed with the project is given for political, personal or intuitive reasons without due consideration of the facts and forecasts in the business plan.
- Senior management fail to support the project manager.

THREE PRIMARY SUCCESS OR FAILURE FACTORS THAT ARE PARTICULARLY RELEVANT TO THE PROJECT EXECUTION PHASE

When authorization has been given for the project to start, it is the contractor (or the main contractor, if there are several sub-contractors) and the project manager who take over most of the front line responsibility for success or failure. Remember that 'contractor' here can mean not only a company that manages or undertakes a project for an external customer, but it also applies equally to an internal manager or team responsible for a management change, IT or similar in-house project. Similarly, the term 'customer' can mean not only an external client or customer, but also the executive management of a company carrying out its own internal project.

The success of the main project contractor and the project manager will usually be judged according to how well they achieve the three objectives of time, cost and performance. Other objectives have relevance to the success of an aviation project as it is experienced by a wide range of stakeholders,

but time, cost and performance are the three primary objectives that will be uppermost in the mind of a dedicated project manager during the execution phases of a project. Many things need to be in place and many actions taken before and during the project execution period to help ensure initial project success in achieving these three primary objectives. Among other things, these include:

- Good project definition and a sound business case.
- Choosing and using the most appropriate project strategy.
- Choosing and using the most appropriate and proven technology.
- Strong support for the project and its manager from higher management.
- Availability of sufficient funds and other resources.
- Firm control of changes to the authorized project (which in aviation projects especially means not only rejecting bad or unnecessary changes but also ensuring that approved changes are recorded to preserve the accuracy of build schedules and post-project traceability).
- Technical competence.
- A sound quality culture with adequate quality procedures throughout the organization.
- A suitable project organization structure.
- Appropriate regard for the health and safety of everyone connected with the project.
- Good project communications, both internally and externally.
- Well-motivated people.
- Quick and fair resolution of conflict.

These issues are all important for good aviation project management.

The Time Objective

Actual progress has to match or beat planned progress. All significant stages of the project must take place no later than their specified dates, to result in total project completion on or before the planned finish date.

Late completion of a project will not please the project purchaser or sponsor, to say the least. In the aviation industry the most common manifestation of late projects is probably when new aircraft are delivered

late to an airline, so that the airline either has to continue operations with its ageing and less economic fleet or, worse still, is not able to open services on new routes as planned.

From the project contractor's viewpoint, consistently failing to keep delivery promises cannot enhance the contractor's market reputation. Further, any project that continues to use resources beyond its planned finish date can have a knock-on effect and disrupt other projects that are either in progress or waiting to follow. Late completion of some tasks by a contractor or sub-contractor might mean that billing for stage payments allowed in the contract will be delayed as a result. Thus a contractor or sub-contractor that fails to achieve some pre-planned milestone events on time cannot bill the customer on the expected dates, and must therefore bear the costs of work in progress for longer than expected—even to the extent of getting into cash flow difficulties.

A common risk to projects is failure to start work on time. Very long delays can be caused by procrastination, legal or planning difficulties, shortage of information, lack of funds or other resources, and a host of other reasons. Even the absence of a senior manager to sign the project authorization notice has been known to delay a project start. Any of these factors can place a project manager in a difficult or impossible position.

A project not started on time can hardly be expected to finish on time. And a project that does not finish on time is almost certain to overrun its cost budgets.

The Cost Objective

Every project should be controlled against detailed cost budgets to ensure that the expenditure authorized in its contract or charter is not exceeded. Failure to complete work within the authorized budget will reduce profits and the return on the capital invested, with risk of a more serious (even terminal) financial outcome if costs are so great that the funds run out.

Most projects are undertaken with the expectation of financial benefits, either on completion or later in their life history. Of course there are projects where there is no initial profit motive, such as many projects carried out by local councils, by other government bodies or by not-for-profit organizations such as charities. But even without the profit incentive the cost objective remains important, not least because all organizations have some limit to the

funds available. A project might have to be abandoned if funds run out before completion, in which case the money and effort already invested (the so-called sunk costs) become forfeit and must be written off. In extreme circumstances over-expenditure could ruin one or more of the contractors or investors.

A word is necessary here in the context of available funds to warn that a project which seems set to be completed within its cost budgets will fail (and most probably bring its contractor down with it) if the cash flows are not correctly managed. That aspect of the cost objective is explained further in Chapter 25.

The Performance (or Quality) Objective

Quality has often been used as an alternative (but less satisfactory) name for the project performance objective. General understanding of project or product quality conjures up several things in people's imaginations. Perceived quality characteristics will depend on the nature of the project or product, but here are a few general examples:

- Performance at least equal to the specification.
- Reliability and freedom from malfunction.
- Long, useful and economic life.
- Safe: posing no unintentional threat of harm to living creatures. (We have to stress the word unintentional here because projects carried out by weapons manufacturers, military aviation contractors, pesticide producers and mouse trap makers are of course carried out with the specific intention of causing harm to living creatures).
- Low operating and maintenance costs.
- Creating a pleasant impact on the human senses (sight, smell, taste, touch, hearing).
- Environmentally friendly.

An airline's project to develop and implement an online passenger ticketing system to handle a daily capacity of up to 10 000 passenger bookings over various routes must be counted a failure if:

- it cannot accept bookings at short notice or sufficiently in advance;

- is too difficult for passengers to understand and use;
- charges incorrect fares;
- allocates passengers to the wrong flights;
- is open to online fraud;
- allows overbooking;
- cannot deal with schedule changes or flight cancellations;
- the website suffers unreasonable periods of downtime;
- the system otherwise prevents some or all of the traveling public from connecting with their intended flights.

If a project is undertaken to reorganize a company, relocate its headquarters and install new IT systems, the IT must perform as expected, and the accommodation and all other conditions must be conducive to staff satisfaction and productivity.

At one time quality in manufacturing and other industrial projects was seen primarily as the responsibility of a quality control department. Great reliance was placed on inspection and testing at frequent stages of each process to discover faults (called non-conformances in quality management jargon), and then arranging for those faults to be rectified. In more recent years there have been many quality initiatives, some originating from Japan, that have attempted to improve the quality of manufacturing and reduce the number of defective items produced.

Quality considerations extend well beyond manufacturing and other industrial projects and are regarded as equally important in the service industries and other businesses. The ISO 9001 series of standards is widely accepted as the base from which to design, implement and operate an effective quality management system in any company, with the ultimate objective of creating a quality culture throughout the manufacturing or service organization. The International Organization for Standards (ISO) publishes and controls the ISO 9001 quality standard and the ISO 14001 environmental standard, which have been adopted as operating models by many companies throughout the world (<http://www.iso.org>).

TRADE-OFFS BETWEEN THE TIME, COST AND PERFORMANCE OBJECTIVES

Of course, the aim of a project manager must be to achieve success in all aspects of the project. But it is occasionally necessary to identify one of the three primary objectives as being of special importance. This emphasis can affect the priority given to the allocation of scarce resources and the way in which management attention is concentrated. It can also influence the choice of project organization structure (which is discussed later, in Chapter 8). Sometimes project managers or their employers have to recognize that they must give special attention to one of the three primary objectives at the expense of the two remaining objectives.

In the mid-1980s Dr Martin Barnes introduced his 'triangle of objectives', the purpose of which was to illustrate that the three primary objectives of time, cost and quality are interrelated and that management priority might have to favor one of them at the expense of the others. That is the only practical function of the triangle of objectives, namely to remind the organization's senior managers that they might be faced with having to make a priority choice between the three primary objectives if they feel that all three cannot be completely assured.

For reasons that we explain later in this chapter, quality is not the most appropriate term for a primary objective and, recognizing this, Dr Barnes soon substituted 'performance' for quality. Since those times he has developed his views further and more recently has replaced 'performance' with 'value for the client'. We shall argue later in this chapter that, when regarding these primary objectives as subjects for choice of management priority, the most appropriate label for this third primary objective appears to be 'level of specification'.

Whenever someone has a good, clearly stated original idea, be certain that others will come along later to complicate things needlessly and spoil the elegant, simple picture. There are many such examples in the techniques and practice of project management. Thus several people have attempted to improve upon the clear and simple Barnes triangle, and it has even been shown in one book converted to a complex three-dimensional vector diagram. Our preferred version is shown in Figure 2.2 in which it is clearly seen that we consider the three primary objectives of project execution to be:

- time;
- cost;
- level of specification.

If senior management wish to remind themselves (and communicate to others) their choice of a priority primary objective, their trade-off decision can be indicated by placing a spot or blob at a suitable place within the triangle boundaries. For example, if cost is the greatest consideration, the blob will be placed in the cost corner. If all the objectives are regarded as equally important, the blob will be put in the middle of the triangle, and so on.

A project for a charitable organization with very limited funds would have to be controlled very much with budgets in mind, so that conformance with costs and budgets would probably exercise the minds of the senior managers most and they would undoubtedly convey those wishes to the project manager.

Industries such as aerospace and nuclear power generation have to place high emphasis on safety and reliability, so that safety, reliability and thus performance to specification must always be the uppermost management objective. Most aviation projects also have to be conducted with high regard for the time and cost objectives. However, a project to schedule a public air display on a specified date at a named airport is so dependent on meeting the time objective that it might be necessary to accept overspent budgets if that is the only way to avoid missing the date, in which case time and performance would become 'joint favorite' primary objectives.

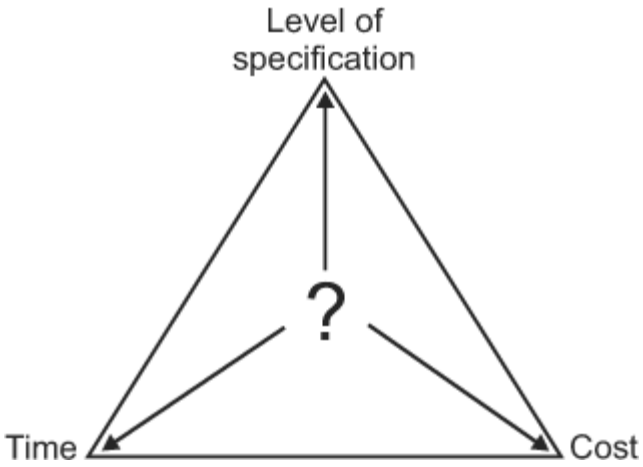


Figure 2.2 Triangle of three related objectives

A Closer Look at the Quality/Cost Relationship

It is a mistake to believe that there can be a simple and acceptable trade-off between 'quality' and cost. Those who promote total quality management argue, quite rightly, that quality can be achieved without extra cost (see, for example, Crosby, 1979). However, there is a fundamental reason why quality is not an objective that can be downgraded in priority or otherwise compromised. This becomes clear if we accept Juran's definition of quality as a service or product that is 'fit for the intended purpose' (Juran and Godfrey, 1999). Clearly no contractor or project manager, whatever the industry, should ever contemplate a project result that is not 'fit for the intended purpose'. Thus downgrading quality is never an acceptable option. Quality is simply *not* negotiable. That is why 'performance' or 'level of specification' are more appropriate names than quality for this objective because, in many cases, they *are* negotiable. The following short examples will illustrate this argument.

Case 1 Suppose that an airline orders a fleet of new aircraft from a manufacturer, after researching the competition and deciding that the chosen aircraft will best serve the intended routes and be the most economical to operate.

Now comes the question of customization for the airline's livery and cabin specifications. It could well be that the manufacturer's initial estimates for the additional customization costs are too high for the airline to afford. The customer still has a strong preference to buy those planes, but the cost and price of branding and customization must be reduced if the purchase is to be made. A period of negotiation will then follow, during which cheaper versions of the cabin design and facilities are discussed, with a view to achieving a price reduction. Maybe the type of floor covering can be changed, perhaps cheaper seats could be specified or the in-flight entertainment facilities could be downgraded.

When the final contract is agreed, the airplanes' quality will not have been compromised because they will still fly safely, economically and reliably. They will still be fit for their intended purpose. But the primary 'level of specification' objective will have been downgraded.

Case 2 An aviation company needs to build new offices. Suppose that the original architect's specification specified deep sunk steel piles for the foundations. If the original project costs are thought to be too high, how about

saving costs by abandoning the idea of piling? Why not build on much cheaper shallow concrete footings? But if the ground conditions demand piling for the building to be safe, that cost-saving option is ruled out on the grounds of reliability and safety. It would compromise quality and is not a true option. A building liable to suffer serious subsidence or even collapse would clearly not be fit for its intended purpose.

Now suppose that the same developer reviews the specification for interior finishes and finds that the specified marble-finished floors and staircases could be replaced with carpeted floors, saving thousands of dollars. The floors and stairs would still be serviceable, safe, reliable and fit for purpose. Carpeting would, therefore, be an option that would not compromise quality. The quality of the project has not been changed, but its level of specification has.

The Time/Cost Relationship

> Remember that TIME IS MONEY!
>
> (Benjamin Franklin, in *Advice to a Young Tradesman*, 1748).

There is usually a direct and very important relationship between time and money. If the planned timescale is exceeded, the original cost estimates are almost certain to be overspent. A project costs money during every day of its existence, working or non-working, weekday or weekend, from day one of the program right through until the last payment has exchanged hands. These costs arise for a variety of reasons, some of which will now be explained.

The effect of project delays on direct costs The *variable* or *direct* project costs of materials and labor-hours are time-related in several ways. Cost inflation is one factor, so that a job started and finished later than planned can be expected to cost more because of intervening materials price rises and increases in labor costs.

There are other, less easily quantifiable, causes where late working implies inefficient working, perhaps through lost time or waiting time (often the result of materials shortages, missing information, or poor planning, communications and organization). If any project task takes longer to perform than its planned duration, it is highly probable that the budgeted labor-hours will also be exceeded. This is true not only for a single task, but also collectively for the entire project.

The effect of project delays on indirect (overhead) costs The *fixed* or *overhead* costs of management, administration, accommodation, services and general facilities will be incurred day by day, every day, regardless of work done, until the project is finished. If the project runs late, these costs will have to be borne for a longer period than planned. They will then exceed their budget. This condition is obvious, for example, in an aviation project where one or more prototype aircraft are undergoing construction in an assembly hangar. Just imagine the additional overhead costs when design errors, manufacturing defects, materials shortages or bungled cash flow arrangements cause work to be interrupted—even for a single day. All those people and all that expensive space and equipment will be standing idle, adding costs to the project without adding value.

The effect of project delays on the costs of financing Another important time-related cost is financing. Where the contractor has an overdraft at the bank or relies on other loan financing, interest has to be paid on the loan. Even if the contractor can finance the project entirely from its internal funds, there is still a notional cost of financing, equivalent to the interest or dividends that the same funds could have earned had the contractor invested the money elsewhere (such as in a bank deposit account). If a project runs late, the financing period is extended, and the total amount of interest or notional interest lost must increase correspondingly.

Much of the finance raised for a large project is likely to be invested in work in progress as the project proceeds through the execution stage of its life history. This work in progress includes not only the tangible results of a project such as construction or manufacture, but also the intangible elements such as planning and engineering or design. In many projects the sub-contractors can only bill the main contractor, (and the main contractor can only bill the client or customer) for work that can be demonstrated as finished. For example, in construction and manufacturing projects the amount of work completed usually has to be inspected and certified by an independent quantity surveyor or engineer before it can be charged out to the customer. The customer will not pay without the receipt of certified invoices. Certified invoices are often linked to planned project events or *milestones.* If the planned amount of work has not been done (or if a milestone has not been reached) a certified invoice cannot be issued. The contractor's revenue is then delayed, which means that the contractor must continue to finance the

mounting costs of the project. The contractor could suffer severe cash flow problems as a result, even leading to bankruptcy in the worst case.

Contractual cost penalties Late completion can invoke the ignominy of contract cost penalties. Although not always easy to enforce, contracts often contain a penalty clause which provides the customer with the sanction of a cost penalty against the contractor for each day or week by which the contractor fails to meet the contracted delivery obligation.

The total cost effect of project delays All these time/cost considerations mean that delays on a large project can easily cause additional costs amounting to thousands of dollars per day. It is clear, therefore, that if work can be carefully monitored and managed so that it proceeds without disruption against a sensible, achievable plan, much of the battle to control costs will already have been won. That, together with good purchasing procedures, is the true foundation for project cost control. As we shall describe in Chapter 24, most other so-called cost control procedures merely collect, record, analyze and report costs.

PERCEPTIONS OF PROJECT SUCCESS OR FAILURE BEYOND THE THREE PRIMARY OBJECTIVES

Most project managers are expected to complete their projects so that they satisfy the three primary objectives of time, cost and specification. These are usually the most important factors that drive the project contractor and they should align with the foremost expectations of the project owner. Most project management procedures (and this book) are directed towards achieving these goals, which could be summarized as delighting the customer while creating a commercial success for the contractor. In this context the contracting organization and the customer are both primary stakeholders in the project.

It must be recognized, however, that many projects (particularly in aviation) have to satisfy more than two primary stakeholders. For example, a bank that has provided loan finance for a project will have a keen interest in whether the project succeeds or fails.

There will always be people and organizations who, while not being principal stakeholders, nonetheless have an interest in how the outcome of a

project might affect them. Sub-contractors and suppliers are an obvious example. Staff working on a project have a stake in the outcome because project success or failure can (apart from contributing to job satisfaction) have profound implications for their future employment and careers.

Perceptions of success or failure will differ between the various stakeholders. The residents of homes lying under the flightpath of a proposed new airport runway would take a very different view from that of the potential airline travelers. A project to build a road transport system that runs out of cash and ruins its main contractor would be an undoubted failure from the point of view of the shareholders, project staff and unpaid creditors, but the road users would not regard that project as a failure if a replacement contractor and fresh cash injections allowed the new road to be opened as planned.

Some environmentalist groups might be dismayed by new project proposals. Many project managers have learned to their cost that work can be seriously delayed by determined protesters, who may be able to publicize a good case, attract a great deal of public support and even trespass on the owner's site or premises to disrupt work.

It is clear, then, that the true measure of project success or failure depends on how the project outcome is perceived by all the stakeholders. Hartman (2000) declares that a 'project is successful if all the stakeholders are happy'. Unfortunately, that ideal may not always be achievable, but it is certainly best project management practice to try to identify all the stakeholders and satisfy their aspirations as far as practicably possible.

IDENTIFYING AND RANKING THE STAKEHOLDERS

The range and nature of stakeholders will vary very greatly from one project to another but the principle of stakeholder identification can be illustrated by a case example. A project has been proposed to expand an existing international airport by building a new international terminal and adding a third runway. This ambitious multi-billion dollar project to expand the airport's traffic handling capacity splits into at several big sub-projects, the most significant of which are:

1. Provide the third runway, together with its associated airside facilities and infrastructure.

2. Design and build the new international terminal building, complete with all its services and systems.
3. Plan, design and implement changes to the airport's surrounding transport infrastructure to cope with the expected increase in passenger and freight movements by road and, possibly, by rail.

Thus this proposed airport expansion is really a program of connected huge sub-projects. It is clear that each of these sub-projects will need its own organization and project management structure, and it is also clear that very many people will be involved in one way or another—or in other words there will be thousands upon thousands of organizations and people who will be affected in one way or another and who can be regarded as stakeholders. The number of different contractors involved will probably run into hundreds and they, in turn, will depend on a huge number of suppliers and other service providers.

Each of these many stakeholders will have their own perception of whether or not the project has been a success. Many will expect to benefit from the airport project, through earnings, through profits and through later realization of benefits when the airport goes into satisfactory operation. But we can envision the misery that will be visited on others, such as people with homes lying below the new flightpaths who must endure nuisance from noise. Worse still, in projects of this scale it often happens that local citizens (who might have little or no personal interest in air travel or airfreight movements) find that their family homes are scheduled for compulsory purchase and demolition to make way for the extended airport boundaries.

Thus the rule for project success proposed by Hartman (ibid) that a project is successful if it makes all stakeholders happy, although it is an admirable moral goal for any project manager, will be put to extreme test in an airport project of this size,. Of course residents subjected to increased noise might be offered help to insulate their home from the worst of the noise, and uprooted home owners should expect to receive adequate financial compensation, but we can hardly expect that these particular stakeholders would be happy and have smiles on their faces.

Listing all the stakeholders for this project would take up many pages, and the list would change as the project moves through the various stages of its life cycle. At the beginning, the stakeholder list would have a high proportion of project workers and contractors, but later these would be replaced by the

airlines, the aircrews, the airport shop retailers and caterers, the baggage handlers, and so on—the organizations and people that will eventually inhabit and work in and around the completed airport extension.

Primary, Secondary and Tertiary Stakeholders

At any time during any aviation project the stakeholders can be listed in groups that rank them as primary, secondary or lower categories. We continue to use an airport expansion project as the basis for this discussion but similar arguments will apply to any other aviation project. The following classifications that we suggest are offered for illustration but the managers of particular projects will make their own minds up on these classifications according to the nature, location and particular circumstances of their project. What is important is that project managers should know who the stakeholders are, and have some idea of how much power or influence they can exert.

Primary stakeholders Primary stakeholders are those people or organizations that have a direct stake in the failure or success of the project. These are the providers of funds, the project owner, the main contractor, the project manager, the airlines, and all those whose prosperity will be materially, immediately and greatly affected depending on whether the project succeeds or fails.

Primary stakeholders can sometimes include independent people and organizations that, although not directly engaged in funding or developing the project, have the power to materially affect its progress and direction. In aviation these can include those regulatory bodies that exercise power of approval or rejection at any project stage.

Secondary stakeholders Just below the primary level there will be a second tier of people and organizations that will be greatly affected by the project, but who can have less direct influence on project design, construction and operation. However, some of these secondary stakeholders can cause disruption (like the more militant environmentalists or local citizens' pressure groups that either oppose the project completely, or want to see it materially changed).

Most of this second tier is made up of the many sub-contractors and suppliers employed during project design and construction. Later in the project life cycle these will be replaced in the second tier by the providers of goods and services needed for the day-to-day airport operations, such as the caterers, security and immigration staff, baggage handlers, check-in clerks and many more.

Those who work in or for the organizations listed as primary and secondary stakeholders will be materially affected by the project progress and outcome, and so must themselves be regarded as secondary project stakeholders. These include staff at all levels of seniority, in companies ranging from the airlines (including aircrew) down to workers employed by the various contractors and sub-contractors.

Tertiary and other stakeholders Outside the primary and secondary groups we shall always find a tertiary group of stakeholders, These will have less influence on the project but, nevertheless will themselves be affected in some measure by the new aviation project and its eventual operation.

For the airport extension project these tertiary stakeholders might include the local hotels, shops and taxi services that will benefit from the general increase in human activity caused in the locality by the airport operations. The local emergency services will also have to take notice of this vast development in their vicinity and be prepared to respond to emergencies that are beyond the control of those provided within the airport itself. Some local government service departments will also be affected.

Realtors can expect an increase in the demand for their services as more jobs are created and people move into the area. These same realtors might also become temporarily busy in serving residents forced to relocate by the airport extension.

Public transport organizations must consider how the airport development will affect their passenger numbers: some of their existing services might need to be changed to suit the new travel patterns (and take advantage of the new business generated). Parents might be concerned that their schoolchildren will have to cross streets that are busier and more hazardous. Motorists and other road users will have an interest in the effect that new road layouts around the airport might have on their journeys.

The Project Manager's Role as a Communicator

Hartman (ibid) has a subtitle in his book that reads '[Bad] Communications: the Only Cause of Project Failure'. Hartman, whose entertaining writing style includes several such dramatic statements, is really saying that a project with bad communications is at serious risk of failure.

It takes little imagination to realize that the more complex a project is, the more difficult it will be to manage communications well throughout the organization. Many aviation projects involve organizations in more than one country, which (even with modern technology) can complicate project communications. Establishing an effective communications framework is an early and important task for the project manager, and in this task the stakeholders must always be remembered and catered for. These good communications will remain important throughout project execution.

For example, in the case of the large airport development project the project manager (or their employer or agent) must keep all the relevant stakeholders informed of the general project planning and intentions long before any actual work takes place. Much can probably be done to overcome opposition from external pressure groups by arranging public meetings, consulting with them, listening to their concerns, and being seen to do as much as possible to work to mitigate their apprehension and let them feel that they are involved in shaping the project. That approach cannot guarantee harmony but the opposite approach of secrecy and silence will certainly generate distrust, conflict and hostility. Open and frank negotiation can usually achieve far more than confrontation.

BENEFITS REALIZATION FROM A LARGE AVIATION PROJECT

We have explained that answering the question 'Has this project been a success or a failure?' depends to a large extent upon which of the many project stakeholders is asked that question.

Most project managers, contractors, sub-contractors and materials suppliers would be content to consider their part in a project as successful if their own portion of the project satisfied the three primary objectives of time, cost and specification (or performance) as soon as their work was done and handed on. In other words, vendors and contractors will be satisfied if they can make satisfactory profits on the goods and services that they provide, and

be confident that their goods and services were supplied fit for purpose. The project manager will be pleased if the project is handed over to the customer on time, without having overspent the budget and to the customer's satisfaction.

Delay Between Initial Project Completion or Handover and Full Benefit Realization

The project owner's perception of success or failure must be based on somewhat different factors from those that drive the contractors, sub-contractors and vendors of materials and equipment. Completion and handover of the initial project (Phase 13 in the project life cycle depicted previously in Figure 2.1) marks only the beginning of the phase during which the owner should expect to enjoy any benefits from the project.

In many projects this question of success or failure (as measured by the benefits realized) is relatively simple. In most industrial and manufacturing projects the project owner should start to realize the expected benefits immediately or shortly after the project is successfully finished and handed over. A chemical plant, once successfully commissioned, will be capable of producing saleable product. A new office building might require attention to the occupier's snagging list during the first few weeks of occupation but should nonetheless provide a pleasant working environment that can immediately improve staff satisfaction (and thus productivity). The purchaser of a new special purpose machine should be able to put it to use as soon as it has been installed and commissioned.

However, business change, IT projects and many aviation projects can be quite different because their most significant benefits cannot be realized until later in their project life history, months or even years into the operating period shown as Phase 14 in Figure 2.1. The following case examples will illustrate this point.

Benefits realization case examples

Case 1: Consider a project that is intended to replace and standardize the customer service and invoicing systems of all the companies in an international group called Flyways International Inc. The execution phase of the project is finished when the IT designers have developed, documented

and tested the software and the associated hardware has been installed at all Flyways International locations worldwide.

The job of writing the software and installing the new computing hardware for this large project would certainly have been contracted out to a specialist company. That IT specialist contractor might have had a successful project outcome, with all three primary objectives of cost, time and performance satisfied at the time of handover to Flyways International (the project owner).

However, the proof of the pudding is in the eating. There is much more to the success of a management change project than the technical excellence and performance of the IT. It is only when the new system is up, running and accepted by the managers and staff of all the companies in the group that Flyways International can begin to regard the project as a success in terms of benefits realization. That implementation process can be long and difficult, sometimes having to overcome difficulties in retraining staff or of managing redundancies as the business processes become more efficient.

Case 2: If an airline decides to open a new route, it cannot expect to realize the full benefits of the project to set up that new route until a sound passenger base has been established, and debts incurred during the set-up project have been repaid from the revenues earned in flying the new route.

Case 3: The manufacturer of a new airplane will not know if the project has been a success or failure until a sufficient number of planes have been sold and put into successful service by the airlines. Full benefits realization will only be achieved when sales revenues have repaid all the design and development costs of the aircraft (which could take as long as 15 or even 20 years).

Summary: From these cases it is clear that benefits realization will generally come sooner in the project life cycle for the main contractor, sub-contractors and suppliers that contributed to a large aviation project than they will for the project owner (whether that owner is an aircraft maker, an airport owner or an airline). Success or failure from the owner's point of view will not become apparent until some time after completion and handover of the initial project, and indeed well into the operational phase of the project (depicted as Phase 14 in Figure 2.1).

There is a converse to all these arguments, namely the fate of a project that is perceived as a failure or even ruinous by some or all of the initial sub-contractors, so that when the project is initially handed over to the owner the

main contractor has lost a considerable amount of money and wishes that it had never contracted to carry out the project. A failed project such as the Denver International Airport or the terrible opening days of Terminal 5 at London Heathrow will eventually be viewed as successful if, many months or years later, the initial problems have been ironed out and largely forgotten and the facilities give good service to thousands of satisfied travelers.

CASE EXAMPLE: DENVER INTERNATIONAL AIRPORT—A PROJECT WITH FAILURE BUILT IN FROM THE START

We include this case as an example of a project that was doomed to failure from its beginning owing to serious differences between planning, economics and politics.

In November 1989, ground was broken to build the Denver International Airport. When the airport opened in late February 1995, it was 16 months behind schedule and billions of dollars over budget. Kerzner (ibid) includes the following quote in his book: 'How does one convert a $1.2 billion project into a $5.0 billion project? It's easy. Just build a new airport in Denver.' Perhaps that's a little unfair to the worthy citizens of Denver, and we note that many places in the world have played host to similar project disasters. There have been many accounts of the Denver project, and the following is based closely on Applegate (1996).

Building the new airport was initially intended to solve a capacity problem that the city of Denver and its environs expected to face. Denver's economy grew in the early 1980s fueled by expansion in the oil, real estate and tourism segments of the economy. It was thought at the time that Stapleton Airport (Denver's old airport) was limiting the attractiveness of Denver and its surrounding areas to businesses that might otherwise relocate to the area. This line of thinking is usually rational in regard to the direct relationship that exists between transportation infrastructure and economic development. At the time it seemed that delays at the airport were common and that a larger airport was necessary.

The proposed airport expansion became a significant issue in a 1983 local government election, and it had some strong political support. By 1986, after political commitment by the mayor, the decision to go ahead had been made.

But subsequently it became clear that the forecasts for activity at Denver's current airport at that time (Stapleton Airport) had been overstated. The traffic projections were too high because they had not taken into account the impacts of post-airline deregulation, the acquisition of Frontier Airlines by Texas Air and the financial difficulties of Continental Airlines—all major players at Denver. Instead of rising, Stapleton's share of the total US domestic market fell by over four per cent per year. This decrease was greater than the decrease experienced nationwide at airports. At the same time, the economy in the Denver area took a sharp downturn. All of these factors, when taken together, indicated that there was little need for the new airport.

What were the problems? First, there was no justification for the new airport. Those involved allowed politics to get in the way of good sound business decisions. All the environmental factors should have indicated that capacity would not be a problem, but minds were influenced by the prevailing political agenda. Thus the strategy of building an airport was implemented on the basis of a flawed business plan.

Another problem with the new airport project was that those in charge of building the airport did not get commitments from the major airlines before building the airport. Only after construction had begun were commitments made, and, as a result, much of what was already constructed had to be changed to meet the demands of the client airlines. Yet another problem was the fact that the airport authority did not pay enough attention to its customers. Without getting commitments from customers at the beginning of the project, a great deal of money was wasted in reconstruction.

CONCLUSION

We have shown in this chapter that the perceived success or failure of an aviation project will depend very much upon which stakeholder's viewpoint is taken and also upon the time during the project's life history when the observation is made.

For the project manager, the contractors and all others who take part during the execution of the project, the three primary factors of time, cost and specification (or performance) are paramount. The project manager bears the most responsibility during this execution phase, but project managers cannot

perform their task satisfactorily without the backing and full support of the organization's senior management.

Later, when the completed project enters its operational phase, the project owner's senior management must implement the project in their organization and ensure that their staff are trained and motivated towards achieving the benefits realization that was envisioned in the business plan.

Wider, different perceptions of success or failure will be held by the many other stakeholders as the project progresses through its life history.

All of this illustrates and reinforces the claim made by Hartman (ibid) that a project is successful only if it satisfies all its stakeholders. Clearly, although the immediate responsibility for project execution lies with the project manager, ultimate responsibility for success or failure of a project is shared by the senior managers representing the project owner and the main contractor.

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3
Project Definition

Clearly every project must be defined as well as possible from the outset because the project customer, the contractor, the project manager and other key stakeholders must all know exactly what end result is expected. This is true whether the intended project is for an external customer or is to be an internally funded development or management change project. A project that has not been defined in sufficient detail cannot be planned, and without a plan there can be no control. For those prefer using longer words, the process of project definition is also known as requirements definition management.

ASPECTS OF PROJECT DEFINITION FOR EXTERNAL AND INTERNAL PROJECTS

For simplicity and convenience we use the term ‘contractor’ throughout this text to identify the organization principally responsible for executing the project, whilst the word ‘customer’ represents the company or organization for which the project will be carried out. ‘Owner’ and ‘client’ are other terms commonly used for the customer.

For projects carried out internally by a company for its own purposes the terms customer and contractor can still be used, even though the customer and contractor both reside within the same group or company. For these internal projects a company must usually pay the project costs from its own funds. Then the project customer will effectively be the company itself, represented by its own corporate management. The department or other internal organization instructed and authorized to carry out the project can be regarded as the contractor. Internal aviation projects can include ventures that will:

- effect organizational change (including company mergers and acquisitions);
- introduce new or changed procedures (whether or not IT is involved);
- recruit, train and develop staff;
- plan and execute downsizing during times of reduced trading;
- acquire new assets (anything from buildings to aircraft) and other facilities so as to increase the company's resources and capacity to undertake work;
- relocate the business;
- design and build a new product (anything from a seat to a complete aircraft);
- bring a new brand to profitable market.

Definition of internal company projects is usually required as the basis for a business plan that sets out the expected project strategy, costs, cash flows and intended financial and operational benefits for the company. There is more on business plans in Chapter 6.

When the project is for an external customer, the time available for investigation is usually limited and the non-reimbursable costs have to be controlled. These nonreimbursable costs typically involve some pre-contract design study, as well as the actual costs of writing and printing the proposal document. However the best definition that is practicably possible within the time and cost limits will be needed before the contractor can estimate the project costs and submit a priced tender or proposal to the customer.

For any project, internal or external, the contractor must know as accurately as possible the scope of work required and the expected performance or outcome of the project.

PROJECT DEFINITION THROUGH THE PROJECT LIFE CYCLE

Early Stages in Aviation Project Definition

Figure 3.1 illustrates the project definition process for a large aviation project in relation to its life cycle. This example might be an airport

development or expansion. Aviation projects often attract public interest for many reasons, not least their possible impact on the local and global environment. Regulatory authorities will take a keen interest throughout the process.

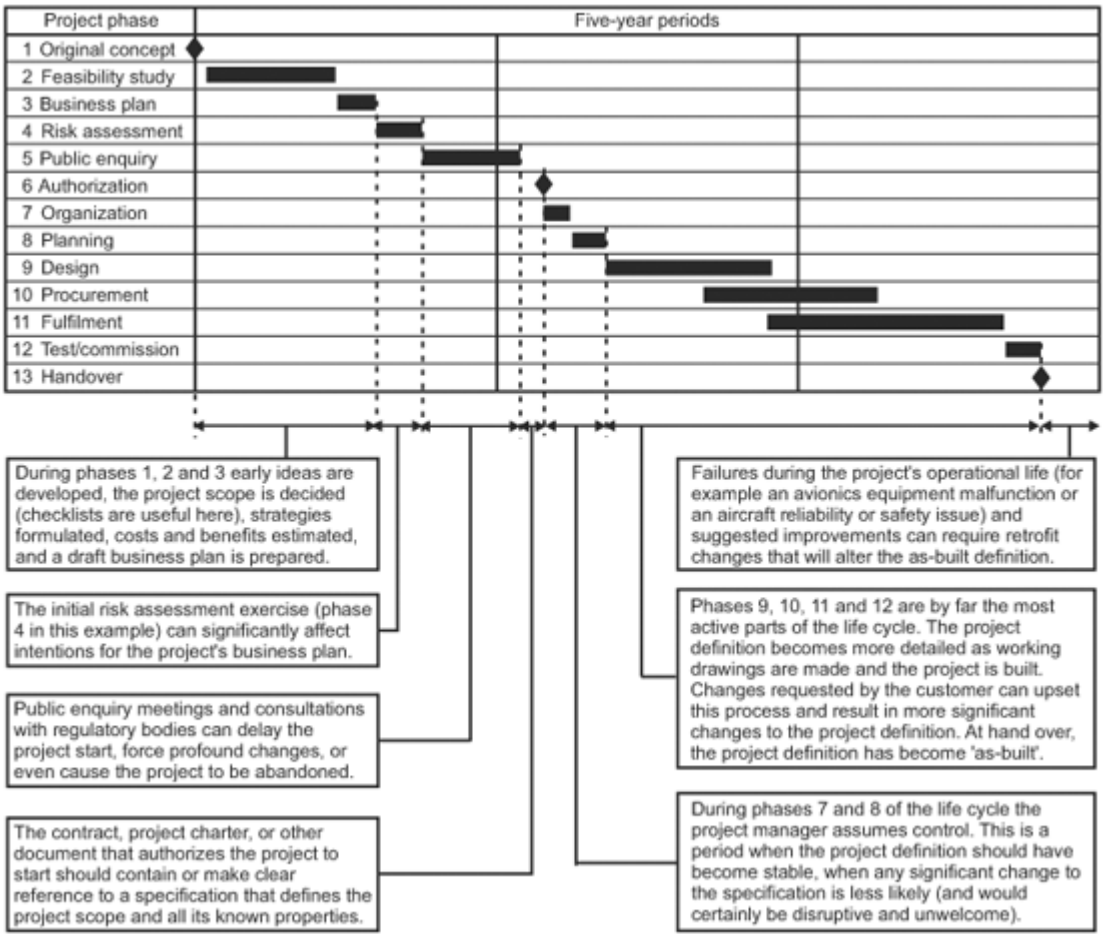

Project phase
Five-year periods
1 Original concept
2 Feasibility study
3 Business plan
4 Risk assessment
5 Public enquiry
6 Authorization
7 Organization
8 Planning
9 Design
10 Procurement
11 Fulfilment
12 Test/commission
13 Handover
During phases 1, 2 and 3 early ideas are developed, the project scope is decided (checklists are useful here), strategies formulated, costs and benefits estimated, and a draft business plan is prepared.
The initial risk assessment exercise (phase 4 in this example) can significantly affect intentions for the project's business plan.
Public enquiry meetings and consultations with regulatory bodies can delay the project start, force profound changes, or even cause the project to be abandoned.
The contract, project charter, or other document that authorizes the project to start should contain or make clear reference to a specification that defines the project scope and all its known properties.
Failures during the project's operational life (for example an avionics equipment malfunction or an aircraft reliability or safety issue) and suggested improvements can require retrofit changes that will alter the as-built definition.
Phases 9, 10, 11 and 12 are by far the most active parts of the life cycle. The project definition becomes more detailed as working drawings are made and the project is built. Changes requested by the customer can upset this process and result in more significant changes to the project definition. At hand over, the project definition has become 'as-built'.
During phases 7 and 8 of the life cycle the project manager assumes control. This is a period when the project definition should have become stable, when any significant change to the specification is less likely (and would certainly be disruptive and unwelcome).

Figure 3.1 Definition of a large project in relation to its life cycle phases

Public inquiries, consultative meetings and other investigations can be expected that will prolong the project definition process in its early stages, sometimes for years. Worse, a change of company management or a newly elected national government can overturn decisions made by predecessors, causing the definition process to be restarted with radically changed objectives or even canceling the idea of the project altogether.

For just one example, consider an airport expansion project, such as a proposal to build a third runway for London Heathrow. Some protagonists will question the need for any expansion of air traffic at all and campaign

vigorously along those lines. Others will suggest that the expanded capacity would best be provided at another existing airport site, thus shifting the regional focus and causing a different set of residents and local regulatory bodies to become involved. More radical (and more expensive) proposals might suggest building a completely new airport, either on a greenfield site or even on reclaimed marshland or on a river estuary. Then we can be sure that the wildlife lobby will also take a keen interest.

So defining a large new aviation project can become a project in itself costing billions of dollars and taking many years to reach its conclusion.

Project Definition Leading to Documentation of the As-built Condition

For most projects the key design parameters and the business objectives must be defined before the project can be authorized to start. However, that initial definition will inevitably be expanded and refined as work on the project proceeds and more and more information is gathered from the work experience. Once authorized, definition gradually becomes far more detailed and accurate as the project progresses through the phases of design, procurement, manufacturing, assembly or construction and final testing or commissioning.

Project definition is thus a continuous process that ends only when the last piece of information has been documented to describe the project in its finished as-built condition. That time comes when the last project task has been done, the final change has been incorporated, and the last bug has been exterminated during final testing or commissioning.

For most projects the final as-built definition point is reached when the project is handed over from the contractor to the customer (or project owner). But in industries where safety and reliability are concerned, post-delivery modifications may have to be designed and implemented. As automobile drivers we have all seen the unfortunate cases where manufacturers have had to recall all vehicles of a particular type within a particular range of chassis serial numbers for emergency modifications to be retrofitted to correct a potentially dangerous fault. This happens also in aviation projects, and the following case is an example.

Example of a post-delivery change to the project specification Suppose that an aircraft has been sold by a manufacturer in varying quantities to

several customers over a few years when a potentially dangerous malfunction occurs in one of the planes, causing it to divert and make an emergency landing at some unintended destination. This aircraft was among the first to be delivered and has therefore clocked a considerable number of flying hours.

Engineers soon track the failure down to a leaking hydraulic pipe. During many hours of flying this pipe has at times been vibrating in resonance with the nearby engine, causing the pipe to chafe and suffer abrasion where it passes through a small hole in a wing spar. The immediate solution for the grounded aircraft would be to replace the pipe and fit one or more pipe clips to anchor the pipe firmly to the wing spar and prevent the damaging vibration.

For obvious reasons of safety and reliability the aircraft manufacturer must be consulted and then that manufacturer has a duty to ensure that this (or some other suitable) modification is retrofitted to all other aircraft of the same design, wherever they happen to be in service and whoever owns them. This modification will change the as-built condition of that aircraft model, requiring modified drawings and, where necessary, amended instructions for regular inspection and maintenance.

Thus the as-built condition of some aviation projects (and the project definition) can change long after initial acceptance by the customer.

SAFEGUARDS FOR PROJECTS WHICH ARE DIFFICULT OR IMPOSSIBLE TO DEFINE

This book generally takes a deterministic and positive approach to project management, which starts from the premise that a detailed specification setting out clear technical and commercial objectives exists when the project is authorized. Of course changes during some projects can affect those objectives (Chapter 23). Further, all projects are exposed to risks to a greater or lesser extent (Chapter 17). However, successful project management ideally requires a determined attitude towards achieving well-defined objectives, with action taken wherever necessary to keep the project on its planned course. All this demands that the customer's or investor's project objectives and the contractor's commitments are well defined and documented in advance.

There are projects that are so complex, or surrounded by so much uncertainty, that they cannot be defined adequately before they start. A few projects cannot even be defined beyond vague outlined intentions, so that the time and money invested in them is something of a gamble, and could either be completely wasted or bring huge rewards. In other words, there are projects for which a proposal or business plan cannot be compiled with the data and forecasts that businesspeople would normally expect to see before making their investment decision. These projects include those for which the proposed expenditure is occasionally referred to as an 'act of faith', a phrase that can strike cold fear into work-hardened financial executives. In such cases special measures must be taken to limit the risks if the idea of the project is not to be abandoned altogether.

Stage-gating

Projects for pure scientific research are an extreme case of initial uncertainty, even to the extent that their outcomes are often completely unpredictable. Chapter 1 mentioned how a step-by-step or 'stage-gating' approach can be used to authorize such projects, releasing resources in controlled amounts *(tranches)* so that the risks can be kept within defined bounds. Each new tranche of investment depends on the satisfactory outcome of a periodical review and reassessment of the project. If the outlook is completely bleak, the plug can be pulled on the project and all further expenditure denied.

Stage-gating is a valuable tool for the sponsor of any kind of project that cannot be defined with certainty in its early days. However, as we hinted in Chapter 1, people working in a stage-gated project are unlikely to be well motivated because they work under the constant threat of sudden project closure. If the employer cannot guarantee equivalent alternative employment on other projects, some staff might feel so insecure that they decide to end the uncertainty themselves by seeking safer employment elsewhere. Fortunately most project managers are not faced with such extreme uncertainty and can adopt other measures to limit their company's exposure to risk.

Contractual Safeguards

Avoidance of fixed-price contracts A commercial contractor asked to embark upon a project for an external customer in which the contractor's expected role is not adequately defined can of course accept the order with some confidence if the payment arrangements guarantee reimbursement of all the contractor's costs plus reasonable fees or profit markups. That method will ensure that the customer or investor bears all the financial risk—not the contractor. Yet even with the promise of full cost reimbursement, poor project definition can still be difficult for the contractor. It is always inconvenient for a contractor to commit resources to a project whose duration is unknown and which is liable to be canceled at short notice.

Provisional cost items in fixed-price contracts for external customers Customers generally prefer to sign contracts against fixed-price quotations, so that they know their commitments and can set their investment budgets with some degree of confidence. Contractors will, understandably, be less enthusiastic about quoting a firm, fixed price when there are significant elements of the project that cannot be well defined.

Contractors (particularly for construction projects) deal with this difficulty by identifying and listing separately all parts of the project that cannot adequately be defined and which are beyond the contractor's control. Those features will be listed separately in the contractor's tender, outside the scope of work covered by the quoted fixed price. These possible additions are known as provisional cost items (and their quoted cost estimates are called pc sums).

Consider, for example, a proposed project to refurbish a disused building where part of the structure is hidden from view and is in uncertain condition. The contractor's fixed-price proposal might be conditional upon no structural defects being found when work starts. A provisional cost item would be inserted in the proposal to indicate the extra costs to be charged to the customer should additional work be necessary when work begins and the true extent of any structural decay or damage is revealed.

Another example is occasionally seen in tenders for the demolition of a building and its replacement with a new construction. Customers sometimes ask that specified items, such as wood paneling, carved figures, doors and partition panels should be saved from the demolition process and used in the new building. The customers' motives might be to save money or to preserve some fond memories of the old building. The customer expects a firm price

to be quoted for the project but the contractor will be concerned that some or all of the items specified for salvage either cannot be saved when demolition starts, or they will be found to be unsuitable for use in the new building. The contractor would cover those contingencies by adding provisional cost items to the fixed-price tender to cover the possibility of having to purchase new materials in place of the unsuitable salvaged items.

Feasibility Studies to Improve Early Project Definition

The investor or organization faced with a very uncertain prognosis for a project might start by commissioning a feasibility study to obtain more facts and expert advice. This study might be conducted by a consultant, by a specialist consulting company or from within the project company itself. This approach is frequently used to examine and appraise the technical, logistical, environmental, commercial and financial aspects of all kinds of projects that require a high level of investment. Banks and other institutions asked to finance or otherwise sponsor ill-defined projects may require a satisfactory feasibility study report before committing funds. Government departments often demand or commission costly study reports for projects which are of significant public or international importance. The Federal Aviation Administration (FAA) engaged in this process with projects such as Next Gen (Next Generation Air Transport System).

A feasibility study for a big capital project can be quite an undertaking in itself, perhaps taking years to prepare and costing many millions of dollars. Aviation is no exception in this respect. For example, a government wishing to develop new defense systems, or to replace its ageing fighter, bomber or military transport fleet, will carry out studies involving not only technical experts and competing manufacturers, but also representatives of the relevant government departments and military chiefs.

Whatever the project, a good feasibility study report can do much to point the project in the right direction, suggest the most effective strategy and define the important risks and achievable objectives.

CHECKLISTS AS AN AID TO PROJECT DEFINITION

Checklists are a very useful way of ensuring that no important task or cost item is forgotten when a new project is being evaluated or a routine

operation is taking place. Contractors who have amassed a great deal of experience in their particular field of project operation will learn the type of questions that must be asked to fill most of the information gaps and they can develop comprehensive checklists for use in project cost estimates and proposals.

Checklist Examples

Routine sales One very simple application of a project definition checklist is seen when a sales engineer takes a customer's order for equipment that is standard, but which can be ordered with a range of options. The sales engineer might use a standard pro forma (either on a pad or a computer screen), entering data in boxes and ticking off the options that the customer requires. People selling replacement windows with double glazing use such methods. So do salesmen in automobile showrooms. Standard forms are convenient and help to ensure that no important detail is forgotten when the order is taken and passed back to the factory or warehouse for action. Included in this category are companies that sell aviation spare parts to airlines or to maintenance and repair organizations (MROs). These parts could be anything from aircraft windows to landing gear tires.

Construction project checklists Airports authorities and other companies about to tender for large projects can make good use of checklists. One such list might be concerned with ensuring that all aspects of the building and performance of a new environmental management system are considered. Another case would be to ensure that the accommodation space and standards in a new terminal building are comprehensively and fully specified.

Local climatic and geological data at an intended airport construction site may have to be defined. The designer or contractor of a construction project at a long distance from its home office may not be aware of hazards such as high winds, earth tremors or flooding. It is also necessary to check whether or not any special statutory regulations apply in the region, which is highly possible in unfamiliar territory overseas. Other data might cover national working practices, religious considerations and customs, the influence of local trade unions, the availability of suitable local labor, facilities to be provided for the contractor's expatriate staff and so on. Many questions

should be asked and answered. Checklists are invaluable in these circumstances. The example in Figure 3.2 is part of a checklist for a project that involves all the civil engineering and construction tasks in building a new airport at a site that is remote from the contractor's home offices, particularly where the site is overseas and little is known initially about the country or the site infrastructure.

Project checklists connected with aircraft design and operations Developers of new aircraft will of course need many checklists, not least of which is the one concerned with conditions that exist at airports that the new aircraft must be able to serve. For example, what local low noise regulations must be satisfied, and will there be any short runways that could prevent access or limit maximum payloads?

Airline ground and aircrew are particularly familiar with the use of checklists in general because pre-flight checks, in-flight checks and post-flight checks must be performed before every take-off, during cruise, before and after each landing to ensure that there are no snags which might threaten the safe outcome of the flight. Similarly it is prudent for all project owners to use a checklist before allowing any project to take off, so that no hidden snags or forgotten tasks will prevent its safe passage to a successful finish.

Checklists for management change and IT projects Internal management change projects can consume prodigious amounts of time, money and other resources but cause considerable harm within and sometimes outside the organization if they fail. Inadequate project definition can be the root cause of such disasters and, here again, checklists are invaluable.

There is often a difficulty in compiling checklists for management change projects when compared with other projects. Organizations that embark on very large internal change projects will probably do so very infrequently, perhaps only once in ten years or longer. Companies conducting multiple, repetitive industrial, aviation or commercial projects can learn from their past experience (and mistakes). On the other hand, companies intending to make big changes to their internal organization procedures and IT do not have the experience of past projects that is essential for compiling checklists. Consultancy companies build up experience over time from their work with many different clients and are thus often able to give advice and help to

define this kind of project. A checklist compiled by one consulting company in the UK (Isochron Limited) is shown in Figure 3.3

Project site and other local conditions

Availability of utilities
- Electrical power
- Drinking water
- Other water
- Sewerage
- Other services

Transport
- Existing roads: Access difficulties (low bridges, weight limits, etc.)
- Nearest railpoint
- Nearest suitable seaport
- Nearest existing commercial airport
- Local airstrip
- Local transport and insurance arrangements

Physical conditions
- Seismic situation
- Temperature range
- Rainfall or other precipitation
- Humidity
- Wind force and direction
- Dust
- Barometric pressure
- Site plans and survey
- Soil investigation and foundation requirements

Local workshop and manufacturing facilities

Local sources of bulk materials

Local plant hire

Site safety and security

Local human resources available
- Professional
- Skilled
- Unskilled

Site accommodation arrangements for:
- Offices
- Secure stores

Site living accommodation for:
- Expatriate managers and engineers
- Workers
- Short stay visitors
- Married quarters (see separate checklist if these are required)

Other site facilities
- First aid, medical and hospital facilities
- Catering and messing arrangements
- Hotels or other accommodation for VIPs
- Local banking arrangements

Communications
- General mail and airmail service
- Special mail or courier service
- Telephone over public network
- Telephone over dedicated terrestial or satellite link
- Fax
- E-mail
- Other

Contractual and commercial conditions

How firm are the proposals?
What are the client's relative priorities for:
- Time?
- Cost?
- Quality?

What are the client's delivery requirements?
Do we know the client's budget levels?
Scope of work envisaged:
- Basic design only?
- Fully detailed design?
- Procurement responsibility: (ourselves, the client, or someone else?)
- Construction responsibility: (ourselves, the client or a contractor?)
- Commissioning, training, operating and maintenance manuals, etc.

How accurate are the existing cost estimates:
- Ball park?
- Comparative?
- Have all estimates been checked against the estimating manual checklists?

How is the project to be financed?
Is there to be a financial guarantor?
What do we know about the client's financial status and payment record?
Are contract penalty clauses expected?
Is the pricing to be firm or other?
What are the likely arrangements for stage or progress payments?
What retention payment will be imposed?
What insurances must we arrange?
What guarantees or warranties will the client expect?

Figure 3.2 Part of a definition checklist for a new airport project

DEFINING PROJECTS PROPOSED BY EXTERNAL CLIENTS OR CUSTOMERS

Inquiries and subsequent orders for commercial projects generally enter contracting companies through their sales engineering or marketing organization. Even when inquiries bypass the sales organization and are received by other members of staff, sensible company rules should operate to

ensure referral to the sales or marketing department so that all inquiries can be ‘entered into the system’ for effective handling and response. This will ensure that every inquiry received from a potential external customer can be subjected to a formal screening process that will assess its potential project scope, risk and value.

010000	**Business analysis**
010100	Business redesign
010101	Major process procedures design
010102	IS procedures design
010103	Data model design (logical)
010104	Report and management information design
010105	Develop procedures documentation
010200	Current state assessment
010201	Information systems review
010202	Use organization assessment
010203	Process assessment
010204	Reporting and MI assessment
020000	**Business change**
020100	Business user training
020101	Identify communities to be trained
020102	Conduct training needs analysis
020103	Develop training plan
020104	Develop training course material
020105	Schedule training events
020106	Administer training events
020107	Deliver training courses
020108	Monitor training feedback
020200	Communications
020201	Identify communication audiences
020202	Develop communication strategy
020203	Select communication media
020204	Develop communication plan
020205	Implement communication plan
020206	Assess audience understanding of key message
020207	Update communication plan
020300	Project contract development
020301	Identify objectives
020302	Identify event milestones
020303	Identify business values
020304	Match flashpoints to value drivers
020305	Quantify values
020306	Determine project cost

020307 Balance value against cost
020308 Develop project contract
020309 Obtain approval
020400 Stakeholder management
020401 Develop stakeholder management plan
020402 Implement stakeholder management plan
020403 Stakeholder analysis
020404 Develop stakeholder role transformation plan
020405 Implement stakeholder role transformation plan
020406 Manage stakeholder issues
020407 Integrate stakeholder mngmnt and communication plans
030000 Project running costs
030100 Facilities
030101 Accommodation charges
030102 IT charges
030103 Room hire
030104 Food and refreshments
030105 Printing and stationery
030200 Overhead allocations
030201 Other contributions to central funds
030300 Project administration
030301 Project accounting

030302	Resource management
030303	Project facilities management
030304	General administration
030400	Project management
030401	Project structuring
030402	Project planning
030403	Project control
030404	Project monitoring
030405	Issue management
030406	Change management
030407	Project reporting
030408	Travel
030409	Hotel
030410	Subsistence
040000	**Technology solution**
040100	Applications support
040101	Design support model
040102	User environment design
040103	IS environment design
040104	Procedures design
040105	Training design
040106	Implement support model
040107	Monitor support services
040200	Custom development
040201	Application infrastructure development
040202	Business system design
040203	Testing design
040204	Data conversion application development
040205	Application software development
040206	System testing
040207	Implementation planning
040300	Hardware
040301	Servers
040302	Clients
040303	Connectivity
040304	Peripherals
040400	Implementation
040401	Data conversion
040402	Acceptance testing
040203	Installation of production system
040204	Refine production system
040205	Evolution planning
040300	Package integration and testing
040301	Installation and environment set-up
040302	Package integration design and pilot
040303	Package business system design
040304	Package application development
040304	Package integration testing design
040305	Data conversion application development
040306	System testing
040307	Implementation planning
040400	Package selection
040401	Package requirements analysis
040402	Vendor and package screening
040403	Package shortlist evaluation
040404	Final evaluation and selection
040405	Contracts and technology acquisition
040406	Development planning
040407	Licences

Figure 3.3 Initial task checklist for a management change project
By kind permission of Isochron Limited

Receipt and Registration of Project Inquiries from Customers

Every inquiry must be registered and given a reference name or number that identifies it uniquely. There is no point in spending time and money in defining a project at the inquiry stage unless it is going to be possible at all subsequent times to know without ambiguity to which inquiry—and, just as important, to which *version* of that inquiry, a particular definition refers. The procedure can be very simple. It only requires a simple register in which the following can be recorded:

- inquiry serial number;
- date of inquiry;
- title;
- customer's name;
- revision number and date of revision (if relevant).

An inquiry register can be used as a simple control that records the progress of each inquiry to make certain that it gets dealt with in the timescale wanted by the customer.

The External Customer's Definition of the Project

Initial inquiries from customers can take many different forms. Perhaps a set of plans or drawings, or a written description of the project objectives will be provided. Ensuing communications between the customer and contractor, whether written or spoken, can be long and protracted, often resulting in subsequent qualifications, changes or additions to the original request.

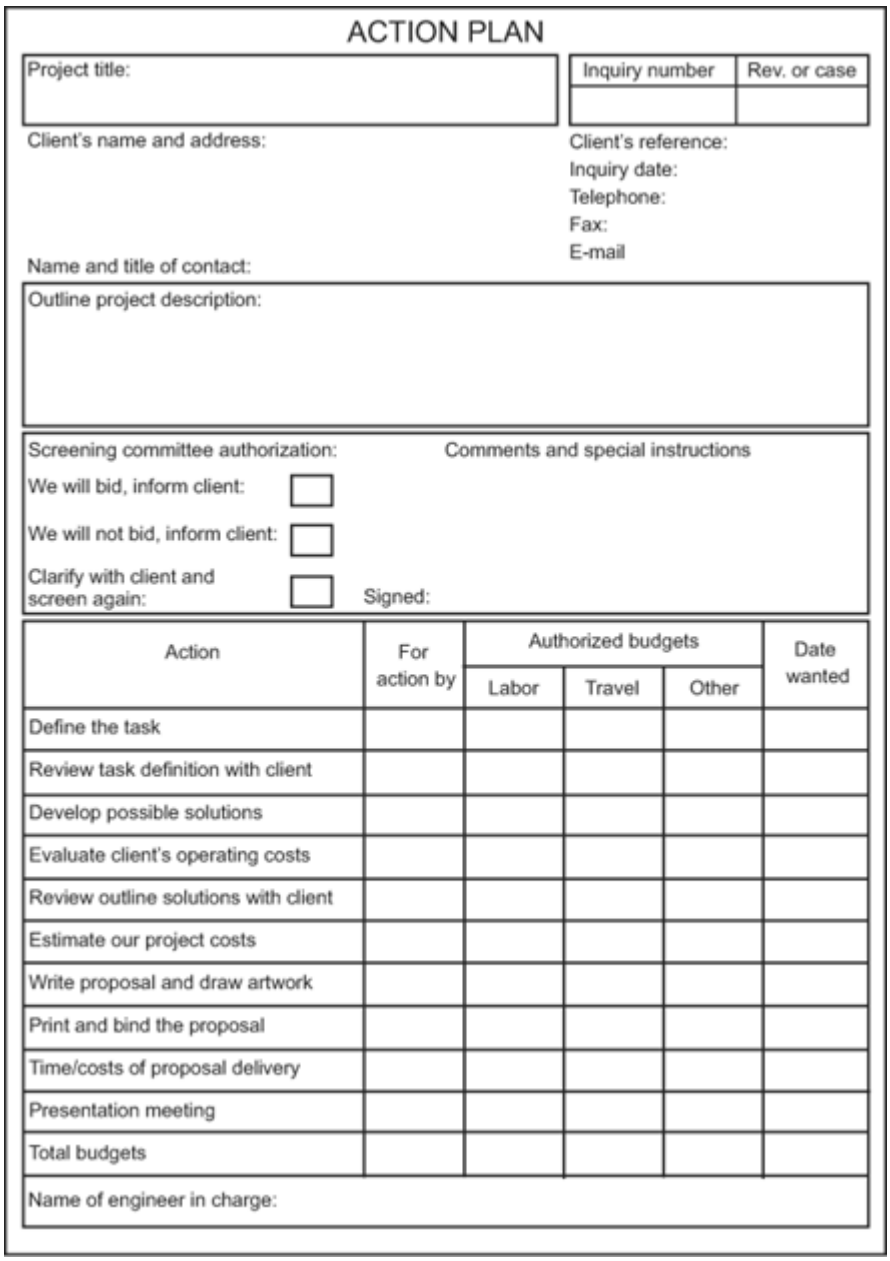
All of these elements, when taken together and documented, constitute the 'customer specification', to which all aspects of any tender and subsequent project authorization must relate. As with all other types of specification, the customer's project specification must be identifiable at all times by means of a unique reference number, date, and the issue or revision number.

As far as the contractor is concerned, the customer's specification begins the process of project definition for projects proposed by external customers.

Screening Inquiries from External Customers

The work involved in checking the project definition and responding to an inquiry can constitute a small project in itself, sometimes needing significant preliminary engineering design work plus sales and office effort that must be properly authorized and budgeted. The contractor will need to assess every new inquiry to decide how to respond. Inquiries from potential customers with a poor reputation for paying their bills or who are not financially sound are likely to be viewed with some disfavor. Other inquiries might be outside the contractor's capability or be inconvenient and unwanted for other reasons.

It is customary, therefore, for companies to subject all inquiries for new projects to a rigorous screening process to determine the appropriate response and either authorize or refuse to commit the time and costs needed to prepare a formal tender. Screening decisions are usually made at fairly senior management level, often at regular meetings held for the purpose. Some companies record their screening decisions and manage appropriate follow-up action using a form for every inquiry such as that shown in Figure 3.4.



ACTION PLAN

Project title:

Inquiry number	Rev. or case

Client's name and address:

Client's reference:
Inquiry date:
Telephone:
Fax:
E-mail

Name and title of contact:

Outline project description:

Screening committee authorization:

We will bid, inform client: ☐

We will not bid, inform client: ☐

Clarify with client and screen again: ☐

Signed:

Comments and special instructions

Action	For action by	Authorized budgets			Date wanted
		Labor	Travel	Other	
Define the task					
Review task definition with client					
Develop possible solutions					
Evaluate client's operating costs					
Review outline solutions with client					
Estimate our project costs					
Write proposal and draw artwork					
Print and bind the proposal					
Time/costs of proposal delivery					
Presentation meeting					
Total budgets					

Name of engineer in charge:

Figure 3.4 An action plan for screening and progressing customer project inquiries

The potential customer will almost certainly set a date by which all competitive tenders for a project must be submitted, so the time available preparing a project proposal is usually limited. Everything must be properly planned, coordinated and controlled if a tender of adequate quality is to be delivered on time. What often happens is that tender preparation starts at a slack pace, with inadequate control, so that insufficient time is left for the end activities of typing, checking, correcting, printing, binding, signing and dispatch. Then there is a frantic last minute rush, with people working all

night to produce the final version and special messengers or couriers given the almost impossible task of delivering the tender by the customer's deadline.

DEFINING THE PROJECT SCOPE

It is important to be clear about the scope of the proposed project. The definition must not make the error of including tasks that external organizations or contractors will undertake, but neither must it omit any significant task from the business plan or definition that would cause estimates, budgets and work schedules to be understated. In other words, project definition involves not only describing a project in its commercial and technical detail, but also in specifying exactly how much of the project work is to be performed by the contractor under the terms of the contract (or in the case of an internal project, the authorized budget) and how much will be carried out other organizations. Put very simply, what is the scope of the contractor's commitment?

For example, suppose we are managers in an aircraft company that is developing a new aircraft to be offered for sale to commercial airlines. All those involved might be very clear on the company's intentions for the new airplane regarding all aspects of its capabilities and performance. But what else is involved in the scope of this project? For instance, do we also have to develop a flight simulator to allow pilot training? Regardless of where the flight simulator is developed and manufactured, shall we be involved in supervising customer training? What other commitments shall we have after delivering completed aircraft to our customers? What about maintenance—do we have to supply maintenance manuals? Do we have to issue our customers with lists of spares that we recommend they buy and stock at their various maintenance hangars? Are all these documents to be in English or do any have to be translated into other languages? The list of such questions might be very long. The answers collectively help to define the scope of the project.

Clearly answers to all of these questions must be found and documented as part of the project task definition before cost estimates, tenders and binding contracts can be considered.

DEFINING INTERNALLY FUNDED PROJECTS

Development programs aimed at introducing additions or changes to a company's product range or to make changes within the organization are prone to overspending on cost budgets and late completion, and these risks are substantially greater if the company's original project intentions were not set in stone in a formal written project specification. A very simple case example demonstrates some of the pitfalls.

Cheepjetz Airways Case Example

Cheepjetz Airways is a small commercial airline that wanted to increase its profitable operations by opening a new route for families wishing to visit a popular holiday location. The proposal was to run daily flights from Chicago O'Hare to Florida, at return fares significantly below those charged by the larger commercial operators. In-flight meals and entertainment would be adequate, but pitched at economy levels. The company decided that part of its marketing strategy would be aimed at working class families with children by offering children's fares at the lowest possible rates. It would be promoted as the 'family service'.

The company had carried out market research and the new operation had been costed very carefully, from which it was concluded that the new service should be popular with families and profitable from the start. The company received approval for the new service from the regulatory authority and proceeded to set up the project. Three months before the new service was due to be inaugurated, the marketing vice president (Jane) needed some promotional ideas, and she called in Jim, a Cheepjetz marketing executive to discuss the way forward. It was suggested to Jim that he might arrange for an introductory gift pack that could be offered as a sales incentive to the first 1000 young flyers using the new service. Jane's idea was that this pack might comprise a small flight bag printed with the company logo containing perhaps a toy and some candies for the children. The flight bag would afterwards be of some use to the parents. These ideas were discussed in haste before Jane departed for an eight-week business trip to visit all Cheepjetz agencies and offices worldwide.

So Jim had effectively been made manager in sole charge of a small project, which was to develop and produce 1000 gift packs suitable for child

passengers contained in flight bags that would display the company logo and be of more permanent use for the parents. But Jim was given no precise instructions, no budget limits and only a vague idea of his project objectives. He was told only that the first flights were scheduled to catch the start of the new Chicago-Florida service, which gave him 13 weeks preparation time and that the gift packs were to be limited to the 'first 1000 young flyers'.

Jane caught the first flight of her extended business trip and Jim wasted no time in getting to work on his small promotional project. He began by commissioning flight bags from a reputable leather goods company, being careful to choose a suitable design from the company's standard catalog range. There was no problem in having these bags customized with the Cheepjetz logo. Allowing for wastage, Jim ordered a batch of 1200 bags at a discounted unit cost of $36 000 for the lot. He could have specified vinyl at a small fraction of that cost, but in the absence of any budget instructions, Jim opted for leather.

For the toys Jim decided on small diecast model airplanes from a supplier's standard range, but these would be a special batch painted in the Cheepjetz livery. They were to be manufactured in the Far East, but the supplier assured Jim that these would be available well before they were needed. Jim ordered 1200 at a total cost of $6000.

Now it was time for Jim to have second thoughts: would these toy planes be welcomed so much by the young female children? So he decided to add a second toy to the gift pack, very similar to a Barbie doll, but dressed in Cheepjetz cabin crew livery. Discussions with a well-known manufacturer revealed again that a standard design could be used, customized using different dyes so that the dress resembled the Cheepjetz uniform. The batch of 1200 dolls would cost $12 000.

Finally Jim had to think about the candies. They proved no problem at all and 1200 boxed packs of assorted sugary morsels, mostly chocolate based, were soon on order for a batch cost of $5000.

Next, Jim turned his attention to publicity. He decided to rely totally on the local radio and television stations. Here Jim did exercise economy and both the radio announcements and television advertisements were to be a message read at suitable intervals by a station announcer on the local radio channel or flashed on the local television company's screens. Jim rushed what he considered to be a suitable script to the broadcasting company. This short message extolled the virtues of this new service and announced the incentive

of a free gift pack to the first 1000 young flyers. Unfortunately this script was not properly checked and it included a significant error, in which the free gift was promised not to the first 1000 young flyers but to the first 1000 flights—a message that was now ambiguous and capable of expensive misinterpretation.

When Jane (the marketing VP) returned from her business trip some four weeks before the new service was due to start, her time was initially taken up with meetings that prevented her from checking on the progress made by Jim. After all, these gift packs were only a tiny part of the work needed to launch the new service. But, relaxing at home in front of her television, Jane was horrified to find that her company was offering a gift pack for the first 1000 flights. The following morning she did check on Jim's progress, when she asked him a number of searching questions and sent Jim away to find the answers. When Jim presented his interim project report, the following facts emerged:

- The toy airplanes from the Far East could not be used because the paint was found to contain lead.
- The dolls would be fine but the supplier had encountered manufacturing difficulties and none could be delivered until one week after the first flight.
- The candies had been stored in the company's general warehouse. But Chicago can get awfully hot in summer and the chocolate had melted and was found to be dripping out of the cardboard cartons.
- Even if all these gift items had been satisfactory, they could not all have been fitted into the flight bag.
- Instead of the promotion being offered to the first 1000 children flying on the new service, all the passengers on the first 1000 flights could have expected to receive a gift pack.

Horrified, Jane called in an external PR company, and asked them to produce a rescue package in the four weeks that remained before the first flight. Unlike Jim, the PR company was careful to have urgent meetings with both Jane and Jim to assess the current position, establish the project requirements, and ensure that these requirements were clearly documented, understood and agreed by all parties. That left three weeks before the first flight, during which the PR company rushed through a damage limitation

project that, for an additional £200 000 dollars managed to provide suitable items that could be fitted into the existing 1200 flight bags and countermanded the promise of gift packs for all passengers on the first 1000 flights.

All this happened because of poor project definition and the lack of precise documented instructions when young Jim was initially placed in charge of the project. Some of the blame must be leveled at Jane because her instructions to Jim were too vague and undocumented. Jim was at fault throughout by paying careless attention to detail. He should have known, for example, that chocolate and high summer temperatures do not sit comfortably together. All marketing executives should be aware of the need to check advertising copy carefully for mistakes, and again Jim failed.

This was of course a fictional case. But readers who think this might be far fetched are reminded that similar promotional errors have happened in the past, on a far bigger scale. One notable example occurred in the mid-1990s when the Hoover company in the UK made two consecutive offers of free flight vouchers to purchasers of its vacuum cleaners. Incredibly no one in the company had realized the financial scale of this commitment and there was a strong attempt to back out of the agreement. But Hoover in the UK and its parent company in the US were forced by determined and prolonged legal action from customers to honor their pledge at a cost reported to be $200 million.

DOCUMENTING THE PROJECT SPECIFICATION

It has to be admitted that documentation, although essential, is not the most exciting or glamorous part of project management. It tends to be regarded with disdain as a subject to be placed alongside routine clerical tasks such as filing. Yet managing information is an expert task. One of us knew a company's information and communications manager who, faced with general staff apathy and carelessness about documentation could often be seen pacing the project offices muttering the mantra 'dedicated documentation' over and over to himself. This perfectly sane man was fighting an uphill struggle to ensure that all the company's managers and engineers followed procedures and treated project documentation seriously.

Given the importance of specifying project requirements as accurately as possible, it is appropriate to end this chapter with some thoughts on the

preparation of a project specification document. The specification enshrines all aspects of the time just preceding project authorization. For internally funded projects requiring significant investment this specification document will probably be part of a detailed business plan (as described in Chapter 6).

Developing a Project Specification with an External Customer

Although customers for projects might be clear from the very first about their needs, it is usual for dialogue to take place between a customer and one or more potential contractors before a contract for any project of significant size is signed. During these discussions, each contractor can be expected to make various proposals to the customer for executing the project. Some of those proposals might suggest changes to the customer's initial inquiry specification—changes intended to improve the project deliverables or otherwise work to the mutual benefit of customer and contractor.

In some engineering companies this pre-project phase is aptly known as 'solution engineering'. Each potential contractor's sales engineering group works to produce and recommend an engineering solution that they consider would best suit the customer (and win the order). Solution engineering might last a few days, several months, or even years. It can be an expensive undertaking, especially when the resulting tender fails to win the contract.

Although it is tempting to imagine the chosen contractor's sales engineers settling down contentedly to write a single, definitive project specification, the practice is often quite different. The first draft descriptive text, written fairly early in the proceedings, will probably undergo various additions and amendments as the outline solution develops. It is likely to be revised and reissued more than once. The text will typically be associated with a pile of drawings, artists' impressions, schedules or other documents appropriate to the type of project. Those documents, too, might suffer several changes and re-issues before the agreed solution is reached.

Projects of all types can undergo a process similar to the solution engineering process just described. For example, the requirements for a management change or IT project are likely to evolve as the various stakeholders make their views known, until a final consensus definition of the project task is reached.

A fundamental requirement when a contract is eventually signed, or a charter is approved for a management change project, is to be able to refer

without ambiguity to the correct revision of the project specification. The correct version is that which defines the project according to the finally agreed intentions. Remember that the *latest* issue of any document might not be the *correct* issue.

The only safe way to identify any document is to label it with a unique serial or identifying number, and augment that with a revision number every time the document is re-issued with changes.

Format and Content of the Project Specification

A well-prepared specification to initially define a medium to large project might typically conform to the following arrangements:

1. *Binder—The* specification for a large project is going to be around for some time and receive considerable handling. It deserves the protection of an adequate binder. The binder should be loose-leaf to allow the addition or substitution of pages when the specification is revised or amended.
2. *Specification identifier*—The binder should carry on its cover the project specification serial number and the project title.
3. *Control schedule for the specification and its associated documents fine the project—This* vital part of the specification complements the specification identifier by denoting the revision status of the complete document. Ideally it should be bound in the specification folder. The control schedule must list every document which forms part of the complete specification. This list should include drawings and other documents that are too large to be conveniently included in the binder but which are relevant to this project specification (for example, layout drawings, engineering standards specifications and statutory regulations). Minimum data required for each document listed in the control schedule are its title, serial number and correct revision number. Should any of the associated documents itself be complex, it too should have its own inbuilt control schedule. This control schedule should be given the same serial and amendment number as the document that it controls. If the specification is numbered XYZ123 and is at revision 6, then the control schedule itself should also be numbered XYZ123, revision 6. Thus the revision status of the entire project specification (including all its

attachments and associated documents) can always be identified accurately simply by one amendment number.

4. *Layout and presentation—The* main body of text and illustrations describing the project should be divided logically into sections and sub-sections, with all pages numbered serially. The main text must be preceded by a contents list that will assist the reader to navigate the document.
5. *Project description*—This text describing the project should be described concisely and without ambiguity, supported where necessary with tables and diagrams so that the project and all its expected performance parameters are fully and clearly defined.
6. *Scope of work*—The scope of work intended for the project must be made clear, reinforced where appropriate by listing work or operations that are not included in the intended project commitments of the contractor.
7. *Amendments or revisions—Every* time a part of the specification is revised, the revision must be identified by a consecutive serial number, and this will raise the revision number of the entire specification. The control schedule (item 3 above) will need to be updated accordingly. Amended paragraphs or additional pages should be highlighted, for example by placing the relevant revision number alongside the change (possibly within an inverted triangle in the manner often used for engineering drawings).
8. *Supporting documents—Most* project specifications need a number of supporting technical and other documents that cannot conveniently be contained within the binder. These effectively form part of the specification and they must all be listed in the control schedule at their appropriate revision number.
9. *Distribution list—A* responsible person must keep a list of all those who received the initial issue of the specification. This can be used as a control document to ensure that all holders of the specification receive subsequent amendments. The safest form of control is to bind the distribution list in with all copies of the specification, although this might occasionally be politically undesirable.

4
Strategic Decisions

Previous chapters have been concerned principally with the description, scope and objectives of new projects. In Chapter 2 we described some of the factors that help to determine whether or not a completed project will be regarded as a success or a failure by the various stakeholders. In Chapter 3 we outlined the process for defining a proposed new project in terms of its physical description, performance and the scope of the work to be done. In other words, so far we have discussed project definition in terms of finding out and specifying what we must deliver to satisfy the project stakeholders.

This chapter turns to the next logical step in establishing a project, which is to decide the most appropriate strategy for executing all the project work. Once we have answered the question 'What must this project do or be like when we have finished it successfully?' it is time to ask the next question which is 'How should we set about doing it?' That means considering the most appropriate strategy for executing the project successfully.

WHAT ARE STRATEGIC DECISIONS?

Strategic and tactical decisions have to be made many times in a typical aviation project as it progresses through its life cycle. The highest-level strategic decisions can profoundly affect whole organizations and hundred or even thousands of people. They can result in the formation of new companies or in the merger or closure of others. Thus decisions of this magnitude can be made only by managers at the peak of the corporate structure or organization. Such decisions comprise what is termed corporate strategy. In addition to corporate level strategy, strategic management theorists typically outline two more general levels of strategy within an organization: business level and functional level.

Strategic management vis-à-vis projects encompasses activities at the functional level in a way that supports business-level strategy as well as

corporate strategy. As a generalization, the higher the strategic level of such questions, the earlier they should be asked and resolved. These questions must be settled early in the project life cycle because the answers will establish the ground rules of how the project is to be organized, managed and funded. Figure 4.1 shows a typical project life cycle yet again, but now our annotations indicate how the life cycle phases relate to the more important strategic and tactical decisions, and suggest the seniority level of managers involved in making those decisions.

In this book we concentrate on strategic questions that must be answered before any project proposal or business plan can be finalized. Until the high-level project strategy has been decided we can have no sound idea of the nature and quantity of resources needed. Estimates of costs and time will be too speculative if we do not know the project strategy and that, in turn, means that cash flows cannot be predicted with sufficient certainty. The strategy finally adopted can also have a profound influence on project risk.

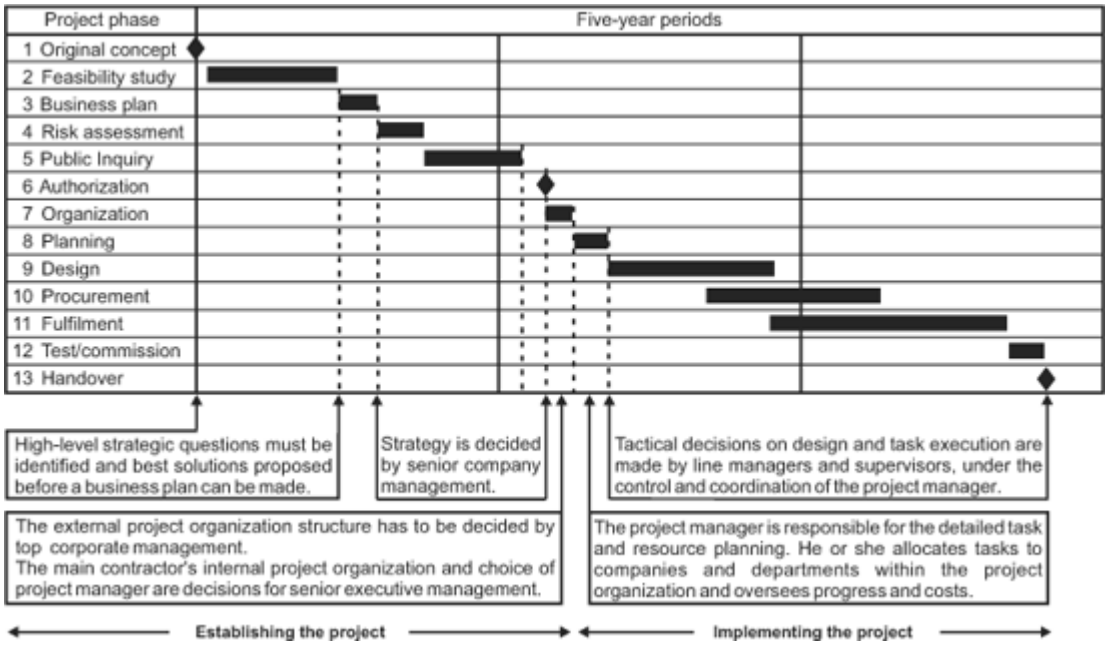

Project phase
Five-year periods
1 Original concept
2 Feasibility study
3 Business plan
4 Risk assessment
5 Public Inquiry
6 Authorization
7 Organization
8 Planning
9 Design
10 Procurement
11 Fulfilment
12 Test/commission
13 Handover
High-level strategic questions must be identified and best solutions proposed before a business plan can be made.
Strategy is decided by senior company management.
Tactical decisions on design and task execution are made by line managers and supervisors, under the control and coordination of the project manager.
The external project organization structure has to be decided by top corporate management.
The main contractor's internal project organization and choice of project manager are decisions for senior executive management.
The project manager is responsible for the detailed task and resource planning. He or she allocates tasks to companies and departments within the project organization and oversees progress and costs.
Establishing the project
Implementing the project

Figure 4.1 Possible strategic and tactical management decisions over the life cycle of a large aviation project

The subsequent phases 14 and 15 (operation and disposal) are not relevant to this chapter and are not shown here.

We shall list the some of the most important and most common questions of strategy here. We also suggest some possible courses of action that

company managers might take or recommend in their business plans. But we cannot be specific and recommend preferred solutions because so much will depend on the particular project, the nature of the business and the business environment in which it operates. Only the top managers of companies or their professional advisers can possibly know the particular circumstances of their businesses and only they will be in a position to make the most appropriate strategic decisions.

EXAMPLES OF EARLY STRATEGIC QUESTIONS AND THE STRATEGIC MANAGEMENT PROCESS

Having a competitive strategy (as distinct from just any strategy) in the way that a project is managed means that a company is doing something different, deliberately choosing a different set of activities from its competitors in an effort to realize better efficiencies (Porter, 1996). Competitive strategic position is of utmost importance in the strategic management of projects.

Competitive strategy means that a firm plans to perform different activities from its competitors, or to perform those same activities in different ways. Obviously it is essential that if a company wants to survive in its business environment, it has to be effective. To be effective a company must perform comparable activities better than its competitors. This might mean that a company has the ability to keep the costs of various operations lower than those of its rivals. Clearly effectiveness is an important factor in profitability differences between firms.

If the activities performed by one company are similar to those performed by another, but better performed, those activities can easily be copied. Once they have been copied, the original company might cease to fare better than its rivals. This is what happened with Southwest and JetBlue in the United States and with Ryanair and EasyJet in Europe—not only in the way that they managed their operations but also in the way they managed their various projects. For a firm to continue to outperform its rivals, it must establish a difference and it must hang on to that difference, preserving it by always thinking ahead. How does a company do this in regard to projects? It must engage in the process of strategic project management (Porter, ibid).

A Case Example

Consider the (imaginary) case of two different airlines that decide at the same time to undertake service from their home country to another country. Let's call that other country Durabia. These companies' decisions resulted from a newly implemented open skies agreement between the two countries. Each airline organizes its new service as a new project and links it to a strategic plan for international expansion into new markets—markets that had until now been underserved because of previous regulatory barriers.

Our first airline, Jordan Air, is a carrier that has emerged from a low-cost background into a hybrid carrier with a multidimensional network and multi-aircraft fleet but with a core strategic and operational belief in the fundamentals of the low-cost model.

Our other airline, Jordan Airways, is a carrier that has been a legacy carrier following a differentiated strategy, focusing on service rather than cost advantages. It always had a multidimensional network and multi-aircraft fleet.

There are two particular factors in the business environment of the Durabia destination:

1. It is a seasonal destination with significant leisure and business traffic in the summer but very low travel demand in the winter.
2. The airline segment is highly unionized with a very elaborate and strict labor law structure.

The strategic positioning regarding the competitive advantage of the two carriers causes them to make very different decisions in the way they organize their project management structure for launching their new service.

Jordan Air, the low-cost carrier approaches this new project in the following way. It:

- picks a handling agent to deal with all operational issues at the new station in Durabia;
- contracts out all primary business functions (finance, accounting, legal, and so on) for a competitive fee;
- maintains corporate functions (such as marketing and planning) at home;
- assigns the establishment project to a Durabian person who has worked for Jordan Air in the home country for decades and thus knows the home

country culture—Durabian culture and language, as well as airline corporate culture;
- establishes the new destination as a seasonal service, and so restricts its off season expenses to the maintenance of a small office at the airport.

As one would imagine, Jordan Airways does the exact opposite. It does the following things:

- creates a full-scale launching project;
- establishes new offices at the Durabian airport and in the adjacent city;
- establishes a local corporate structure in Durabia, hiring people for primary business functions, corporate functions and operational functions;
- launches a hiring program in the home country and hires several local employees, establishing a full handling organization for the new operations;
- establishes a project management structure to handle the launch program for the new service. This involves several departments and people.

This case highlights how different organizations can manage their projects strategically, by linking them directly to their individual customary corporate strategy and hence their competitive advantage. Which of the two above mentioned airlines is most successful in the short or long term would depend on market, industry and economic characteristics. However, it is evident from our exaggerated example that Jordan Air clearly has the advantage in terms of cost and versatility.

THE STRATEGIC MANAGEMENT PROCESS

There are six important tasks in the strategic management process:

1. Establish corporate values through a vision statement and a mission statement: Corporate values are the cornerstone on which the company resides; they are what the company believes in. A strategic vision is an articulation of the company's desired future by organizational leaders. The corporate mission provides a more detailed account of that vision,

answering the questions, ‘Where are we going?’ ‘Who are we?’ and ‘What are we doing?’

2. Set corporate objectives: A company must set specific performance targets within the realm of the corporate vision and mission. In order to be worthwhile, corporate objectives must be measurable and attainable, and they should answer the question, ‘Where do we want to be in year X?’
3. Determine strategic alternatives: Strategic alternatives come from an analysis of the external and internal environments. Strategic alternatives are the vehicles used to achieve corporate objectives, and they answer the question, ‘How are we going to get there?’
4. Select strategy to support the corporate objectives: The selected strategy should be the vehicle that improves the competitive position of the company.
5. Implement and execute strategy: Implementing and executing the strategy means getting all the resources in order and then putting the strategy in place.
6. Evaluate, monitor, and adjust: A company must evaluate its performance through constant monitoring and make adjustments when new developments warrant corrective actions. Sometimes adjustments require alterations in the mission, objectives, strategic alternatives and selected strategies. The importance of environmental scanning cannot be emphasized enough.

Whilst these stages seem clear cut, there is a great deal of interdependence and overlap between them. The corporate values, vision, mission and objectives are generally crafted such that each one is reflected in the other. In other words, the values of a company help shape its vision and mission. Yet even these tasks cannot be accomplished without a clear picture of the company’s internal capabilities and the environmental forces affecting the company and the industry in which it exists. Without an honest assessment of the company’s capabilities, implementation will be compromised. Strategic management is dependent on accurate information, well thought-out assumptions, honest evaluations and sound judgment.

Corporate values, particularly with regard to ethical behavior and social responsibility, have received a great deal of attention in the aftermath of the Enron and WorldCom debacles in previous years. The subject is very important in project management as these values are another link between the

way in which a company practices social responsibility as a whole and, specifically, how this spills over to projects.

Corporate values are considered by some to be the core element in the drive to become competitively dominant. These values are the uncompromising guiding principles of a company and its projects. They are used to motivate employees and to give employees something in which to believe. In effect, these values shape organizational attitudes and employee behaviors. Yet sometimes corporate values are little more than a few words —often clichés. For example, annual reports throughout the world use such statements as 'integrity', 'customer service' and 'excellence'. These are represented as the values of the company, the essence of its existence. Project management strategy needs to be intrinsically tied to a company's corporate social responsibility.

Corporate values guide and define how a company should treat its employees, shareholders and customers. By definition, corporate values should do the following:

1. remain intact regardless of changing business cycles or economic swings;
2. be relevant and applicable to every person in the organization;
3. be applied consistently regardless of issues;
4. remain constant regardless of staff or management changes. (French, 2002).

For corporate values to play a meaningful role in organizational effectiveness and for these values to form the foundation for creating and maintaining the organization, they must be first-order. In other words, corporate values should be derived from a fundamental philosophy about what actually constitutes the good of the organization. The values are management's attempt to define the 'organizational good', both in the context of organizational life and in all of the actions and endeavors in which the organization engages. First-order values should be the very reason the organization exists; in essence, they are a constitutional framework for corporate governance (Giblin and Amuso, 1997).

Many corporations take these first-order values one step further by placing the good of the organization in a societal context. This is known as social responsibility. Social responsibility has become an important value for many companies trying to focus on moral and societal issues and events. Social

responsibility revolves around the idea of giving something back to society, whether it is in terms of monetary donations, sponsorship of events or ethical words by which to live. Much of the current interest in social responsibility supports the belief that an ethical overtone is in the best interest of the company. It is a kind of Hippocratic Oath for a business, which tells the customer exactly what to expect from the company.

Even more important today is the issue of ethical behavior as part of the company's core value system which must be the absolute case in the ways that projects are structured and managed. Company stakeholders want to see a written commitment to ethics in business dealings. A 2002 study by the American Management Association (AMA) indicated that 76 per cent of the 175 executive respondents listed ethics and integrity among their core corporate values. In addition, 86 per cent reported that they had written corporate values that were disseminated to employees through handbooks, brochures, wall posters or websites. However, despite the emphasis on corporate values, the same study revealed that 32 per cent of these companies did not necessarily follow their corporate values and that their written word was often quite different from their actions (AMA, 2002). Many people might find this last statement very disturbing. The corporate values, vision and mission should provide the foundation on which an organization is built and moves into the future and corporate values should exist and should be followed in all operations and projects.

Another very important aspect of a company's strategy that project managers should understand, believe in and follow is its strategic vision which is an articulation of the company's desired future by organizational leaders; it is truly an integral part of the strategic project management process. One of the first important steps in the strategy process is establishing a corporate vision. Top managers are responsible for crafting the corporate vision and managers in different levels of the organization, including project managers, of following it. It should answer such questions as the following:

- Where should the company be in the future?
- What is the direction in which the company is headed?
- What place should the company occupy in the marketplace?

Establishing a vision requires management to take a close look at the company, its capabilities, its product and its competitiveness. It forces managers to focus outside of the organization on the market and the industry and make some tough decisions as to where the company can best succeed. The vision reflects the aspirations and ambitions of the top managers with respect to the company, and a strong vision means that it becomes the guiding perspective and driving force of the organization. Put succinctly, a strategic vision should provide a sense of commitment and cohesiveness for the organization.

A significant business issue is that all too often the vision is nothing more than a statement that top management is aware of but to which the employees, customers and even the stockholders may never have been exposed. A study by the National Institute of Standards and Technology (NIST) confirmed just this. Prepared by Harris and Associates, this study of 300 executives from large US industrial and service companies revealed that while 82 per cent of the individuals interviewed said that they had a definite vision of what they felt their organization should be in the future, and 79 per cent of them thought that a long-term vision was necessary for the survival of their companies, only 38 per cent felt that their visions were broadly shared within the organization (NIST, 2003).

A vision that is never articulated cannot be very clear to anyone outside of top management offices. If it is not very clear to anyone outside of top management, how are the employees supposed to believe in what the organization is all about? Logically, if the vision is not shared and, therefore, people are not aware of it, then how can a company say that a vision exists? Westley and Mintzberg (1989) said that if vision is to exist it must be the result of an interaction between the leaders and followers, and the vision should empower everyone involved.

The vision company forces managers to think into the future. If a manager does not know where he or she wants to be in the future and does not know the direction to steer the business, how can he or she run the business? The vision provides the future path for the business. Therefore, the strategic planning efforts should support the vision and also inform the organization's vision. What does this mean? Through planning efforts, managers become aware of the environment around them. As the environment changes project managers will begin to realize the effectiveness of their vision.

QUESTIONS OF PROJECT DEFINITION AND METHODOLOGY

Project definition can pose difficult strategic questions. Further, most aviation projects involve technical design problems that can be solved by more than one possible solution. Answers to some technological questions can be resolved during the design phase after a project has been authorized but some technical approaches are so basic that they must be decided, or at least recommended, during the project establishment phase.

Here are some examples of strategic questions concerning project definition or technological solutions that might crop up during the project establishment phases of the life cycle for a project to develop a new airport or to design and build a new aircraft:

- Should the new airport have one all-purpose terminal building or do we need separate buildings for domestic and international flights?
- How many runways do we need? Where should the runways be located in relation to the terminal(s)?
- How do we address environmental management requirements?
- How long should each runway be or, alternatively, what is the largest aircraft that we should be able to accept?
- What form of runway construction do we envision?
- Do we contemplate using advanced technologies such as carbon fiber airframe components or shall we prefer to use more traditional materials?
- What target market and deployment do we have for our aircraft that would shape our decision of its size and design?
- What environmental profile will our aircraft have? Who will be the power plant providers and what would the technical specifications of the power plant be to address noise and emission regulations?

These strategies must be formulated before the business plan can be developed because they will affect project costs and duration, and thus funding requirements. Some questions will also raise matters that must be resolved with the relevant statutory bodies before an airport development can go ahead or before an aircraft can be considered for certification.

QUESTIONS OF PROJECT RESOURCES

Project Funding

Airport development projects and programs for the design of new commercial or military aircraft usually require enormous resources. Using those resources involves committing very large sums of money, often with no prospect of any return on that investment for many years. It can, for instance, take as long as 20 years before a new aircraft project begins to show figures on the profits side of the ledgers. Thus establishing project funding is usually a major strategic factor. Are the funds to come from existing reserves, from bank loans, from a new share issue or from sale and leaseback of real estate? Or should the level of investment needed (and the risk, and the opportunities) be reduced by going into partnership with another company?

Project Accommodation

Aviation projects usually need large premises. Of course for airport construction projects the airport site (once acquired) should provide all the space needed but aircraft development projects need phenomenal amounts of space in the shape of design offices, manufacturing plant and assembly hangars. For example, the Airbus A350XWB requires almost 800 000 square feet of factory space just for the first part of its final assembly. A company contemplating a new aircraft development project also has to take into account the possible simultaneous use of its available premises on other development projects or on the routine manufacture of aircraft for existing airline customers.

A company must know well in advance of a project being authorized how much space it is likely to occupy, and for how long. This is not just a matter of guessing how many square feet the project will occupy. Project space has to be considered in terms of physical properties such as clearance height, the standard of environmental control required, quality of lighting, load bearing properties of the floor, and all other properties that the intended operations will require and that those working in the premises will expect.

Location is another important consideration. Will suitable accommodation be available in our existing premises or must we search for additional space or even build accommodation? With modern electronic communications

distances between different premises working on the same project have become less important but what about regional factors, such as the availability of suitable labor, local regulations, transport and means of access?

All these strategic questions should be considered as part of establishing the potential project before authorization. One complication is that these questions are often connected with other strategic decisions, particularly for large aviation projects. For example, if a decision is made to invite one or more partners to join the project, so that some design, manufacture and assembly will take place elsewhere, that will clearly reduce the main contractor's space requirements.

Sub-contracts or Partnerships to Extend In-house Technological Capacity and Competence

Aviation projects always require design engineers and manufacturing facilities that are able to work using advanced technologies over a wide range of systems and equipment. To give just a few examples, an airport project will need people to design, build and install baggage handling and check-in systems and it is most unlikely that the main airport contractor would have the necessary skills. Similar arguments apply to many other airport systems, one most obvious example of which is the air traffic control system. Thus an airport development project is likely to require the participation of many different specialist companies. The way in which these specialist companies are chosen and included in the project organization is one of the most important high-level strategic questions that will have to be resolved before the project can be fully defined in the business plan.

The developer of a new commercial aircraft would not be expected to have the in-house capability to develop and manufacture all the major components. Many components will have to be bought in. The engines are an obvious example, and these will certainly be purchased from a company that specializes in aircraft power plants. Some sub-assemblies and even parts of the airframe might have to be contracted out and it is not unknown for the main contractor to engage a partner or sub-contractor to build components as substantial as the wings.

Here, again, is a case where high-level strategic decisions must be made when the project proposals are being formed to answer the questions 'What

can we design and build ourselves and what must we contract out?' 'Do we need one or more partners for this project?' 'If we do need outside cooperation, should we engage participating companies as sub-contractors?' 'Or should we bring invite them to join us in some kind or consortium or joint venture arrangement?'

An important point to consider in this context is the availability of willing partners. At the time of writing this chapter (mid-2008), the Nevada company Aerion had already accepted many advance orders (in the form of letters of intent and refundable deposits) for its $80 million supersonic business jet aircraft (SSBJ). But Aerion had yet to find a partner willing to commit itself and the billions of dollars needed to take this project to certification (source <http://ainalerts.com/ainalerts/alerts/052108_PF.html>).

A willing partner may not be a suitable partner. For example, a candidate for partnership might already be working with one or more competitor companies. If that candidate is adopted as a partner, there is a danger of divided loyalties should, for example, the new partner find itself short of resources and having to juggle priorities. Worse, because of the complex network of ownerships between different groups and their subsidiary companies, it might not be apparent that a potentially suitable partner is directly (or more likely indirectly) owned by a competitor group.

QUESTIONS OF IN-HOUSE MANAGEMENT COMPETENCE

This section deals with the unthinkable—do our company's existing in-house managers have the competence to make the necessary strategic and tactical decisions that are so vital at this project establishment stage?

Later, if a proposed project is eventually authorized to proceed to implementation, shall we have to make changes to our organization, or set up an entirely new management organization and, if so, do we have the necessary competent management experience and skills staff? Or, in other words, would proceeding with a proposed new project mean making senior management changes?

Maybe this question is embarrassing and it brings with it difficult personal issues of loyalty and comradeship. But if there is any doubt over the competency of existing managers anywhere in the organization to handle the

proposed project should it become live, now is the time to ask the questions and look for the answers.

The first place to seek evidence on a manager's performance is his or her record on previous similar projects. Those who performed badly in the past are at strong risk of doing so again. More difficult is the case of a proposed project with no comparable predecessors, so that there is no in-company record of managers' competence to direct or work on the proposed new project.

Management skills can be acquired through training, and provided there is enough time the performance of some existing managers might be improved through counseling or training in project skills. However we are reminded of the case (which one of us experienced) when a senior vice president of a large American group addressed managers of one of its UK subsidiaries. He asked the question, 'What would you do if one of your people (let's call him Mr Smith) failed to perform to acceptable standards?' Various members of the audience attempted to answer the question by recommending training, counseling, setting performance incentives and so on. 'And what if Mr Smith continued to show little or no improvement?' asked the senior VP. More suggestions were made from the floor. Exasperated, the VP shouted 'No, you fire him' (expletive deleted). Sometimes strategic decisions need firm measures.

Part of early project strategy might mean looking outside the organization covertly to earmark potential recruits should the proposed project go ahead. Recruiting and inducting senior managers into an organization is not a 24-hour operation. It can take several months before a suitable person, once found and tempted, can obtain release from his or her current employment. So the time to consider such needs is not when the project starts, but as part of contingency planning when formulating the project strategy.

SWOT ANALYSIS AS A TOOL FOR CONSIDERING THE COMPETITION AND BUSINESS ENVIRONMENT

SWOT analysis (also known as internal-external analysis) is a well-established tool that gets its name from the initial letters of the words strengths, weaknesses, opportunities and threats. It has been used for many years by marketing people and senior managers to help determine a

company's internal strengths and weakness and also to consider market opportunities and possible threats. SWOT analysis helps to provide a good overview of where the company stands competitively and influences the way it undertakes its projects and how it designs them. The premise of the SWOT analysis is that a good strategy must be the byproduct of the company's internal resources and capabilities and the situation in the industry. A good project strategy most come from a holistic view of the business, taking into account both the external pressures as well as the real issues surrounding the capabilities of the firm.

SWOT analysis is ideally suited to brainstorming sessions. When any strategic decision for business change or a new project is considered, input from the meeting delegates can be recorded on flip charts for subsequent consideration and analysis. Four flip charts can be used, with one of each dedicated to strengths, weaknesses, opportunities and threats. This method is illustrated in Figure 4.2, which is an imaginary case showing how the flip charts might look early in a brainstorming session to consider the case for establishing a new airline route.

Identifying Strengths

Identifying company strengths as well as the strength of its project management structure should be easy if one does a thorough analysis of the internal environment. A company's strength is something that the company does particularly well, or something that is a positive asset. A strength is something over which a company should have control. For example, the company has control over its core competencies in establishing and implementing them. It also has control over its resource capabilities as well as its corporate balance sheet. A strength is internal to the company. Strengths can be identified by examining the company's value chain. Another way to find strengths is through an examination of the functional areas within the company.

Identifying Weaknesses

As with strengths, identifying company weaknesses should be easy if a project manager performs a thorough analysis of the internal environment. A weakness is something that the company does not do well, but over which it

has control and sometimes the potential for improvement. For example, the company has control over its financial picture, but this does not always mean that the money is being managed appropriately. It also has control over its products and services, but this does not mean that the products and services are good.

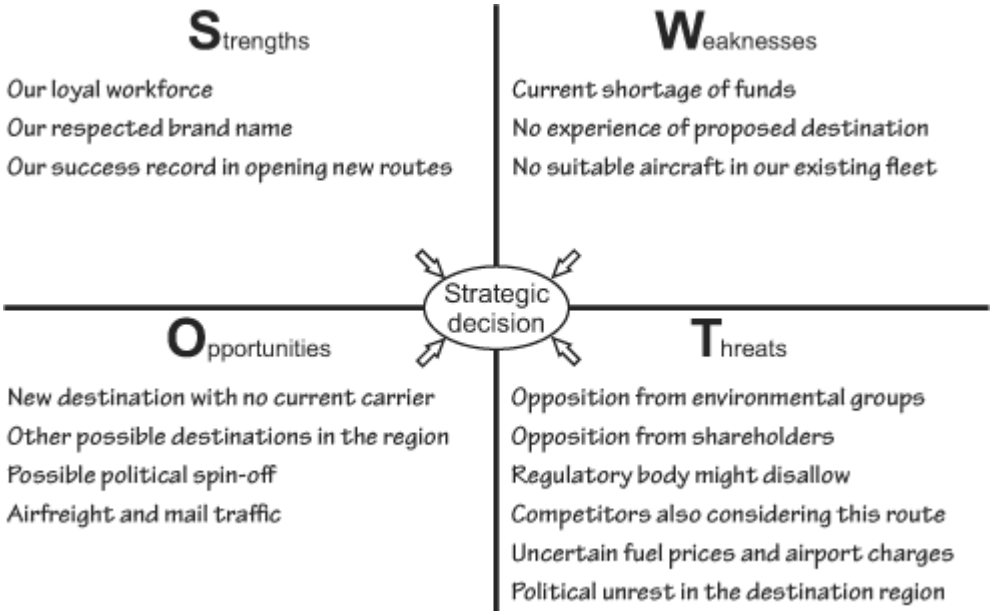

Strengths
Our loyal workforce
Our respected brand name
Our success record in opening new routes
Weaknesses
Current shortage of funds
No experience of proposed destination
No suitable aircraft in our existing fleet
Strategic decision
Opportunities
New destination with no current carrier
Other possible destinations in the region
Possible political spin-off
Airfreight and mail traffic
Threats
Opposition from environmental groups
Opposition from shareholders
Regulatory body might disallow
Competitors also considering this route
Uncertain fuel prices and airport charges
Political unrest in the destination region

Figure 4.2 SWOT analysis—part of an analysis for a proposed project to open a new route

It could be that the company's project management practices are no more than a copy of a competitor's product, and that is no guarantee of a competitive advantage for the company. Competitive advantage and, most importantly, sustainable competitive advantage are difficult to duplicate. Competitive advantage typically resides in human resource structures and practices rather than in technology or operational practices.

So, both in regard to strategic project management and in general, the ability of a company to develop a project management structure that can be linked to a sustainable competitive advantage is a significant value-added feature.

A weakness is internal to the company. Weaknesses, like strengths, can be found by examining the company's value chain or by taking a close look at each of the functional areas. The most important thing about determining weaknesses is to be honest and introspective and avoid rationalization. It is always easy to determine strengths because those are the things of which the

company is proud. But how about weaknesses? Strategic analysis is no better than the time and effort put into the analysis and no better than the honesty of the evaluation. Therefore, it is essential in the analysis to admit to all weaknesses.

We must also keep in mind the paradox that something can be a strength and a weakness at the same time. For example, a company might have a very motivated workforce (strength), but they might not have the expertise needed to move the company into the next generation product (weakness). In this scenario, the employees can be considered as both strengths and weaknesses and project managers should be cognizant of this reality and utilize it to the company's advantage.

Identifying the Opportunities and Threats

The next area needed to complete the SWOT analysis is the external analysis of the opportunities and the possible threats. After a thorough analysis of the external environment, company management should be able to determine the opportunities and threats or constraints that face their industry in general and the company in particular. These are things within the business, political and physical environment over which the company has absolutely no control.

There are different levels of these opportunities and threats. Some exist within the industry, but others, like economic issues, exist at the macro level. Nevertheless, all these things have an effect on the way a company conducts business.

By making a thorough assessment of the external environment the opportunities should be easy to spot. Opportunities are factors that exist in the external environment of which the company can take advantage. For example, a political change in a country that was previously regarded as hostile can open up the possibility of new air routes. A foreign country that is perceived to be enjoying greater than average economic expansion will probably be in a position to increase its purchases of both military and commercial aircraft, and all the ancillary services that go with that trade. Company management cannot control opportunities but they can certainly look out for them and use them to enhance the company's strategic position.

As with opportunities, a company has no control over a constraint or threat, but a threat can do a lot of damage to the business if not managed properly. Common threats arise internationally from political changes, where

perhaps a coup will overthrow a friendly government and replace it with one that is less friendly or openly hostile. The most extreme kind of political threat is, of course, the outbreak of a war. Economic conditions that change for the worse can pose threats, whether the problem lies at company level or is national or international. Then there are threats from pressure groups that might, for example, delay or even prevent projects such as airport expansions. Threats can also occur in the natural environment, whether these are natural disasters or longer-term changes.

It is a sobering thought that we were able to imagine and list many more weaknesses and threats than strengths and opportunities.

Strategic Responses to a SWOT Analysis

After identifying all the components of the SWOT analysis the next step for the project manager should be to get from the SWOT analysis to developing competitive project strategies tied to the overall competitive strategic positioning of the company. The strategies should be a seamless intermingling between the internal environment and the external environment and should provide a natural fit with the company's internal resources. In other words, management should use strengths in the internal environment to either exploit some identified opportunities or to protect against external constraints.

Organizational flexibility is key to transforming an internal weakness into a strength, or changing an external threat into an opportunity. Currently, airlines that are well suited to capitalize on opportunities, which may exist as a result of further liberalization internationally, are those that have an organizational structure that is flexible enough to provide customers with what they need in the future. Air transportation, today, is not a luxury commodity as it was in the 1950s and 1960s. Operators who can satisfy the needs of their core customers through distinctive competences will be the ones who succeed, whether those customers are leisure or business.

If a project, in the context of a business strategic plan, has been able to establish a distinctive competence, its strategy must support that competence. However, a distinctive competence will not last forever unless it is cultivated. In order to cultivate a competence, one must look toward the future and make sure that management continues to build the strong resource base that got the company to its present state. One should look to next-

generation technology or perfect operational processes so that, as discussed previously, it will be next to impossible for the competition to reproduce.

Another important point is that, with any given strategy, often there are critical issues that must be addressed prior to moving forward. Generally, these critical issues are internal to the company, like an unfavorable balance sheet or poor, inefficient equipment. It may be imperative for management to clean up the internal mess before moving forward with a new strategy. If it is a cash flow problem, then maybe it is time to sell off some unproductive assets. Overall, moving forward with a new strategy may not be possible until some of these critical elements are handled.

Finally, the SWOT analysis can give a project manager a good snapshot as to where the project and company are at the present moment. It also helps to assess exactly where the company is in terms of the internal organization. Sometimes, through SWOT, management gets a good overview from which to determine exactly what must be done in the near future to improve competitiveness. For example, SWOT might reveal to a company that there is great urgency to make changes in the organization if it wants to remain viable in the market. Thus, while SWOT helps to formulate strategies, it also gives a very thorough, and hopefully unbiased, overview of the company.

FORMULATING PROJECT STRATEGY UNDER UNCERTAINTY

Because every project is unique and new in some way, all projects abound with risk and uncertainties. Thus project strategy formulation is all about uncertainty. But while uncertainty creates challenges, it also gives rise to opportunities. Although uncertainty brings the realization that some of the best determined project strategies might not work out, this can be exciting and a source of opportunity. Most people are not fans of uncertainty. However, stable, steady environments provide fewer opportunities in which companies can grow and prosper.

How do project managers prepare their projects to take advantage of the opportunities that might come about as a result of uncertainty? They must first understand the drivers of change and then formulate strategic responses to deal with those drivers. Some suggest finding a strategy robust enough to weather any situation, although this is easier said than done. There is no one

prescription for every situation, and if such a strategy exists, the pay off versus the risk is likely to be watered down. Project managers always want the highest possible pay off. If a strategy can fit a multitude of situations, is it really the best strategy for the company?

Teisberg's Six Steps

Teisberg (1993) described six steps to developing insights into uncertainty as a generic model applied to strategic management situations. Her six steps are as follows:

Teisberg's first step: brainstorming Brainstorm a list of uncertainties that the firm faces and examine the logic of how these uncertainties may unfold. Teisberg suggested making this list as expansive and as inclusive as possible, including possible changes in demand or supply, possible strategic moves or repositioning by the competitors, changes in the complexion of the competitors, and possible changes in technology, demographics and substitute products. Further, she suggested including in the list any political uncertainties, economic, social or even acts of nature. Finally, Teisberg noted that some of the outcomes are dependent on the actions of the competitors in the industry and that others are dependent on the firm itself. The key is to understand the interrelationships among uncertainties and between uncertainties and possible responses.

Teisberg's second step: identify the strategic choices Identify strategic choices the firm can make and consider the interrelationships among decisions and uncertainty. At this point, Teisberg suggested developing a decision tree. (An example of a decision tree is given in Figure 4.3). Decision trees help a manager make a choice between several courses of action. They provide a structure within which the manager can lay out options and investigate the possible outcomes of the options. Decision trees also help to form a balanced picture of the risks and rewards associated with each option. Teisberg suggested that company managers ask themselves, within the structure of the decision tree and given the possible scenarios, what are the best options for the company? She cautioned not to look at decisions as good or bad, or whether or not they would constrain the strategies in the future. The reason for developing the decision tree early on

in the process is that it provides a framework for getting ideas out on the table and looking at how they might unfold under different environmental conditions.

Teisberg's third step: develop visions of the future Develop internally consistent visions of the future that challenge conventional views. By developing scenarios it forces the strategist to look beyond simple forecasting and create some viable alternatives for the future. There is no set number of scenarios that should be developed, but it is important that the strategist develop enough scenarios to provide contrasting views. At this step it is important to ask such questions as the following:

- What could possibly happen that would cause buyers to be more price-sensitive (or less price-sensitive)?
- What must occur to change the situation in the industry such that profit margins plummet?
- Are there possible substitutes on the market, or is there a situation where a product might be rendered obsolete?
- Could a product become a commodity and, if so, what would this do to the industry?

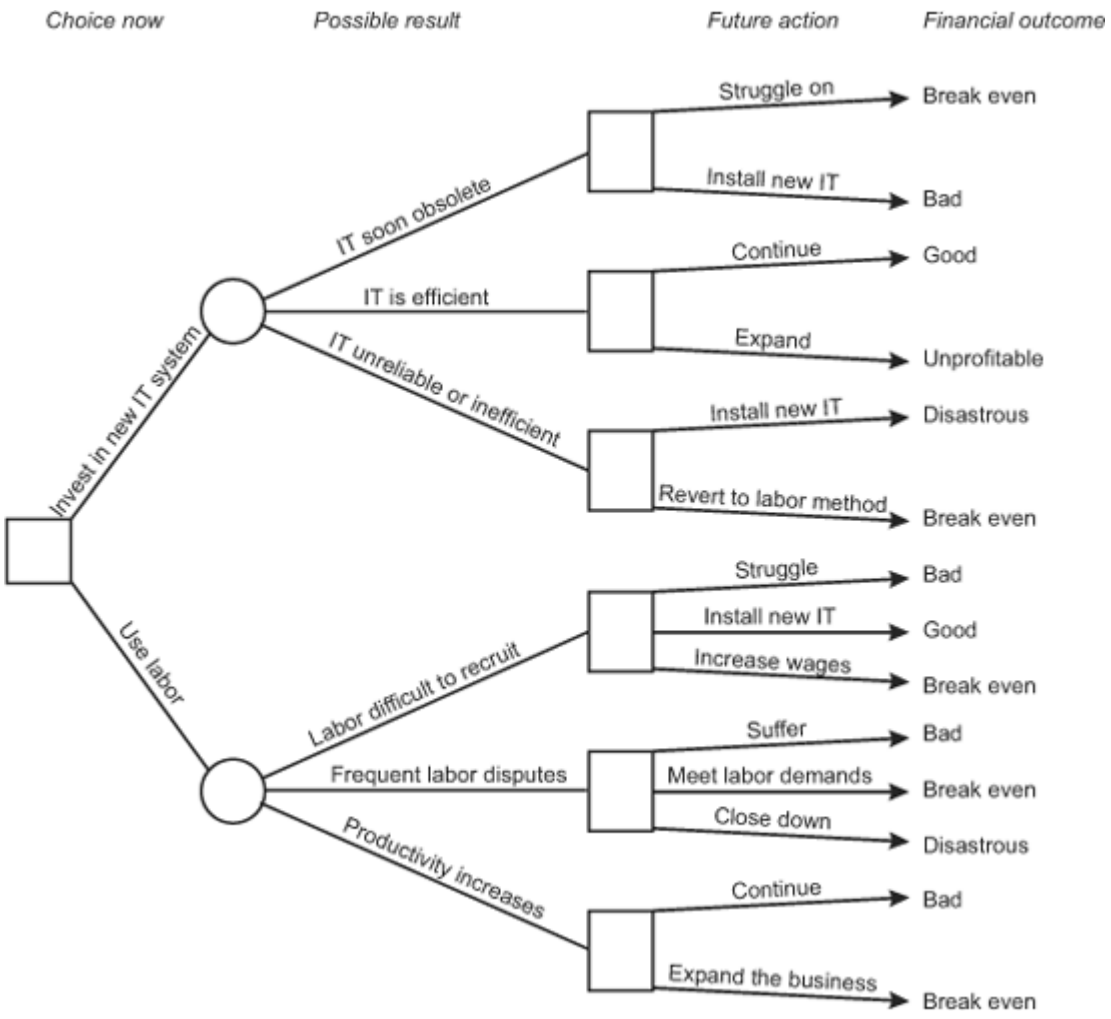


Figure 4.3 A decision tree example
Adapted from: Lock (ed), (1998), *Gower Handbook of Management*, Aldershot, Gower.

There are countless other questions that should be addressed, but these are examples of those that might cause the strategist to think outside the box. While many people who support scenario development suggest having best and worst case scenarios, Teisberg said that it is more advisable to establish many different scenarios with credible outcomes.

Teisberg's fourth step: check whether uncertainty is critical to decisions
Sometimes it makes more sense to come up with several different alternatives, because one might find that uncertainty really does not have much affect on the strategic decision. In these cases, management does not have to give uncertainty another thought, at least for a while. If a firm's major decisions would be the same under every scenario, then uncertainty is a

minor player and not worth the distraction. However, if a company's decisions would be the same under every scenario, it could also mean that the uncertainty was not characterized appropriately. Before going any further, the analysis should be reassessed.

Teisberg's fifh step: analyze how the firm's decisions may affect future uncertainties and the development of the industry Teisberg suggested that it does not make sense to assign probability to each scenario because it is not certain if the list of scenarios is complete. Instead, at this point, she suggested asking questions like the following:

- What can the firm do that might influence some of the more important events?
- Is there something that can be done to pre-empt moves by competitors?
- Do regulatory outcomes depend on plans or commitments of the firms in the industry?
- Is there a chance that some of the less aggressive competitors might become viable opponents?
- Is there a way that management can reinvent the industry to avoid destructive competitive battles?

Teisberg's sixth step: formulate strategic responses to uncertainty by considering the firm's activities throughout the value chain Uncertainty is not likely to hit all aspects of the value chain at one time. Differing activities might be affected at different times. In other words, look at the whole picture. A manager wants to make sure that whatever choice is made supports the company's strategic direction; sometimes this means reducing the risk at some points of the value chain in order to gain the greatest pay off in the end. For example, maybe a company needs to stock more inventory than normal to be able to respond more quickly to environmental circumstances.

Choice of Responses to Uncertainty

There is no single response that works best for all situations for all project managers. Some managers are much more averse to risk than others, and some companies have a history of conservative decision making. Managers have several categories of choices they can make: (Teisberg, ibid)

- choices of bets;
- choices of robustness;
- spreading risk;
- hedging;
- investing in flexibility;
- choices of timing;
- choices that change uncertainty.

Choices of bets Bets are commitments to high-risk investments, and high risk usually brings about high pay-offs. However, if management makes the wrong decision, they can also lose big! Of course, there is an element of 'betting' in all management decisions, but good managers do not just bet. They make decisions based on some facts. This is often called taking risks (manageable) but not gambling (unmanageable). Managers need to look for the opportunities with the highest pay offs, and at the same time be careful not to rely on only one plan. They must use other strategic responses to complement the bet.

Choices of robustness Choice of robustness means taking steps to reduce manageable risks. If management reduces risk across all activities in the value chain, then they are probably diluting the overall strategy, and the likelihood of being competitive is drastically reduced. Instead, it is important to be selective about the choice of activities. How are manageable risks reduced?

Speading risk The most common way to spread out risk is to invest in several different courses of action. For example, leading companies in the industry might want to be aware of all the new technologies on the market that could set new product standards. For example, managers in these leading companies will most likely want to protect the firm's leadership position. Therefore, to avoid being caught off guard by a technology shift, they may choose to invest heavily in R&D as well as diversifying R&D efforts. By spreading out risks in R&D, companies can focus their investment further along the value chain in product improvements. Smaller firms, on the other hand, cannot afford to dilute their efforts by spreading resources over a wide range of products. There is always a drawback when choosing to spread out risk: the potential loss of strategic focus.

Hedging Another measure that managers might take to reduce risk is strategic hedging. Imagine a company that has developed new, next generation technology but is unsure how this will be received in the marketplace. Management is hedging its bet that this technology will be successful. However, to reduce the risk involved in failure, the company might also invest in the development of a less advanced, more common type of technology on which to fall back. Of course, the downside to this scenario is that management could end up spending more money and resources trying to avoid the risk than it might have cost to face the risk head on.

Another example of hedging is exemplified in partnerships or joint ventures. Yet while managers may argue that these relationships provide a way for avoiding bad outcomes (for example, competitive dominance by another company), these arrangements often mean that company knowledge, contacts and distribution channels are shared with the competitor. In this situation, the risk potential might surface some time in the future.

Investing in flexibility One last option for reducing manageable risk is through investing in flexibility. This could mean investing in new production facilities, which make it easier to change gears with relatively few switching costs. It could mean looking for ways to reduce the 'brick and mortar' and change to a 'point and click' environment. The idea of creating core competencies, as discussed in previous chapters, lends itself well to investing in activities and resources that create flexibility for future product development (Hamel and Prahalad, 1990). The key to investment in flexibility is to make sure the company outlook is looking toward the future. Management must always consider the question, by changing things now, will it pay off in the long run?

Choices of timing Strategic choices are not simple 'yes' or 'no' decisions. Timing can have drastic effects on the outcome of the strategy. Some believe timing is everything, and in the case of strategic decisions it might be true. Knowing when to take a product to market or when to enter a new market can be imperative to the ultimate success of the strategy. Sometimes it is a matter of planning the strategy in multiple stages, testing the water before committing the company's resources and energy. Sometimes uncertainty makes people delay their decisions, and delays could cause the strategy to fail. On the other hand, a delay may be exactly what is necessary for a

strategy to succeed. Sometimes delaying strategic choices allows the manager to understand the situation more clearly. However, some opportunities are only available for limited times. Project strategists must learn to strike when the time is right!

EARLY DEALINGS WITH REGULATORY BODIES OF THE AVIATION INDUSTRY

The aviation industry is, rightly, beset by regulation, and all projects from their inception to completion are influenced or controlled to a greater or lesser extent, whether these are for new airports, new aircraft, engines, other equipment, and the provision of air carrier services. Regulation is a cornerstone characteristic of the industry as it exists to guarantee the safety of air transportation and those that work within the industry as well as its customers and the general public. The link of regulation and strategy is both apparent and of significant importance. Regulation directly impacts strategy as it sets the boundaries for safe operations. Projects must comply with these boundaries otherwise their feasibility is questionable and the issue in strategic project management is one of project efficiency that would translate for operational and strategic efficiency.

Project management typically deals in the 'lower' levels of strategy. Conventionally, project management is a tool for functional-level strategies that spill over to business-level strategies. However, our argument is that given the great importance of regulation in air transport, project management links functional- and business-level strategies to corporate strategy as corporate strategy must reflect regulatory compliance.

International, national and local government bodies in the aviation industry can have significant influence on new project proposals. Unless a project meets regulatory and legal requirements it is non-viable. Therefore regulation is a precondition for aviation project management, not least because the regulation of safety is a very serious business.

Global aviation regulation at the intergovernmental level is regulated by the International Civil Aviation Organization (ICAO). However, ICAO is not itself a regulatory body. It is an intergovernmental organization (an IGO) that provides a forum for the international coordination of national aviation policies and regulations. ICAO issues Standards and Recommended

Practices (SARPs) rather than the regulations themselves. Each country or regional block has its own regulatory authority that is tasked with the management of safety (the Federal Aviation Administration (FAA) in the US is one example) as well as other agencies and ministries that manage various aviation regulatory issues (economic, financial, security, environmental and so on).

Depending on the nature of specific projects, national regulatory compliance in addition to compliance with international standards that aim at the international harmonization of operations, national and local laws and standards are incredibly important. For example, for paving a new runway or building a new hangar, in addition to local and national civil engineering and environmental standards that have to be met in the definition and implementation of the project, things like compliance with national and international markings, signage, lighting, and so on are very important.

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5
Estimating the Project Costs

Cost estimates are necessary for all projects, and cost re-estimates are often needed at times throughout the project life cycle. Without a cost estimate it would be impossible to carry out financial appraisal or prepare a business plan for a new project. Project management requires cost estimates to establish detailed budgets, help control spending, assess manpower requirements and perform many other management procedures. A company's sales executives, sometimes in committee with their more senior company management, must rely on cost estimates when deciding the price to be offered in proposals to external customers for aviation projects.

INTRODUCTION TO COST ESTIMATING

There are several reasons why cost estimating is not a popular pastime with technical people. Those asked to put aside more creative work whilst they give thought to the possible costs of future projects will regard the exercise as an unwelcome distraction. Yet they know just how difficult cost estimating can be. Get it wrong, and their mistakes or bad judgments in this important function will come home to haunt them in the future. Cost estimating is an onerous task but it carries great responsibility.

Some companies employ cost or estimating engineers whose only role in life is to live with cost estimating and cost reviews. Other companies assign the cost estimating task to their line managers. However, whatever the original source of cost estimates it is always wise and recommended that experienced line managers should be involved in the process. These managers should at least be asked to review and approve the cost estimates that will ultimately become their own committed working budgets.

A cost estimate for a large aviation project will collect a great amount of data. This brings us to another aspect of cost estimating, which is that it must be approached with great formality. All the data must be recorded and

assembled in a logical way, which will help to ensure that no item is forgotten and that all aspects of the cost estimate are available for the near and far future. This will be important when the time comes to convert the estimates into departmental and task budgets (discussed in Chapter 24) and also for the benefit of future estimators, whose work will be greatly facilitated if they have access to readily retrievable cost and budget records from past projects.

Figure 5.1 shows a summary cost estimate as it might be set out for a small aviation project. The arrangement shown here would apply to the project at a point in its life cycle where the contractor had assembled enough information about the project to arrive at a proposed selling price.

The arrangement for an internal management project or a self-funded R&D program might be somewhat different. In those projects there is no external customer and therefore no project selling price. Companies typically treat all such project costs as indirect or overheads, so that they expect to recover the costs in their absorption costing process (which means from present or future sales revenue).

Even in the introduction to this chapter we are using cost terms that might be unfamiliar to scientific and technical people who work in projects, so we need to take a break here to list and define some essential terms used by cost accountants and cost estimators. Those who work with costs as part of their profession know that the word ‘cost’ can sometimes be too vague and should not be used alone, without saying what kind of cost is meant. A few cost accounting terms that occur frequently in project work are listed in the following section.

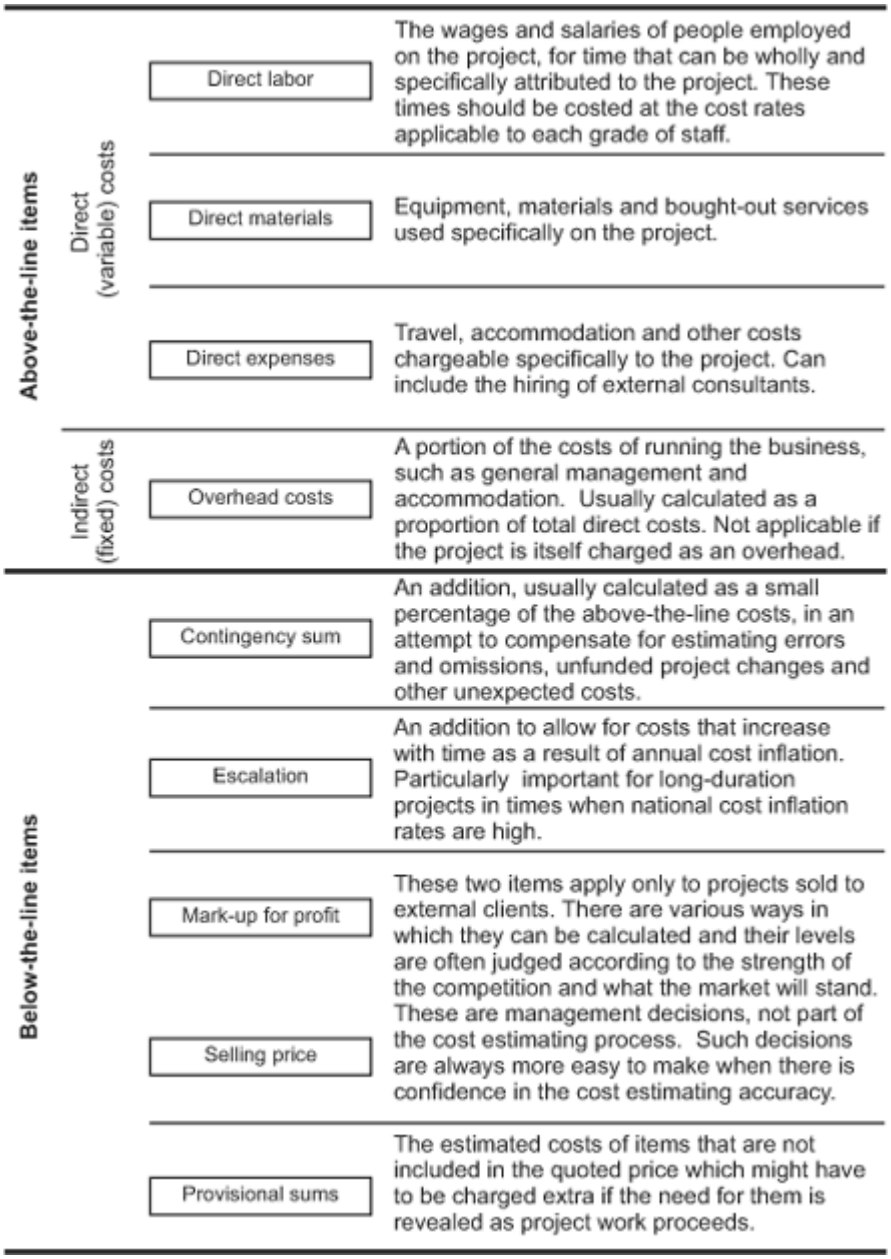

Above-the-line items
Direct (variable) costs
Direct labor
The wages and salaries of people employed on the project, for time that can be wholly and specifically attributed to the project. These times should be costed at the cost rates applicable to each grade of staff.
Direct materials
Equipment, materials and bought-out services used specifically on the project.
Direct expenses
Travel, accommodation and other costs chargeable specifically to the project. Can include the hiring of external consultants.
Indirect (fixed) costs
Overhead costs
A portion of the costs of running the business, such as general management and accommodation. Usually calculated as a proportion of total direct costs. Not applicable if the project is itself charged as an overhead.
Below-the-line items
Contingency sum
An addition, usually calculated as a small percentage of the above-the-line costs, in an attempt to compensate for estimating errors and omissions, unfunded project changes and other unexpected costs.
Escalation
An addition to allow for costs that increase with time as a result of annual cost inflation. Particularly important for long-duration projects in times when national cost inflation rates are high.
Mark-up for profit
Selling price
These two items apply only to projects sold to external clients. There are various ways in which they can be calculated and their levels are often judged according to the strength of the competition and what the market will stand. These are management decisions, not part of the cost estimating process. Such decisions are always more easy to make when there is confidence in the cost estimating accuracy.
Provisional sums
The estimated costs of items that are not included in the quoted price which might have to be charged extra if the need for them is revealed as project work proceeds.

Figure 5.1 Typical summary layout of a project cost estimate

COST ACCOUNTING TERMS COMMONLY USED IN PROJECT COST ESTIMATING AND COST CONTROL

Absorption costing—a method that attempts to recover indirect costs (overheads) from sales revenue by apportioning them over all the company's direct costs.

Below-the-line-costs—a collective name for various allowances that may be added once a total basic cost estimate has been made. Below-the-line costs typically include allowances for cost escalation, exchange rate fluctuations, contingencies and provisional cost items.

Cost escalation—increases in the costs of labor and materials can cause project costs to rise above their original estimates or budgets with the passage of time because of national or international cost inflation. Increases in wages and salaries, higher commodity costs and increases in the prices of materials and equipment can all contribute to cost escalation. Cost escalation becomes especially significant in projects that are expected to last for several years. However, in aviation the cost estimates used in business plans and the costs of some project operations can be suddenly and severely affected by international commodity prices, especially the cost of oil and, therefore, aviation fuel.

Cost of sales—equivalent to the sum of all the above-the-line costs shown in Figure 5.1.

Direct costs—costs of labor, materials and other expenses that can be directly attributed to project work. These are also classed as *variable costs*, because their rate of expenditure varies with the intensity of project activity. When no work is being done on the project there are no direct costs.

General and administrative costs—a general cost burden, added as a proportion per cent of the above-the-line costs by some companies to recover marketing and other general expenses (for instance head office costs) that are not included in the overhead costs.

Indirect costs—costs that must be incurred by the organization to provide heat, light, accommodation, insurances, maintenance, accountants, secretaries, welfare, management salaries and other general running costs of the business that cannot be attributed as costs to be charged to a specific project. Because these costs do not vary from day to day they are also *fixed costs*. They are also generally equivalent to *overhead costs*. However, the administration and accommodation costs at a construction site for an airport project would be a special exception because all those costs *can* be directly attributed to the particular aviation project and can therefore be treated as direct costs.

Labor burden—an amount, usually a percentage of wages or salaries, that is added to the basic hourly or weekly rate for employees to allow for non-

working time and various additional expenses such as the cost of paid holidays and *per capita* amounts payable by the employer as employee benefits, either voluntarily or as a requirement of the national legislation. For project cost estimating and control it is convenient to include this burden in standard labor cost rates.

Materials burden—an amount added by some contractors to the actual cost of bought out materials to recover their purchasing administration costs. This might be charged at ten per cent or less for very high-cost goods but at (say) 25 per cent on small low-cost items that have relatively high handling and administration costs. A common all round rate often used for the materials burden is 15 per cent.

Overhead rate—more properly called the overhead absorption rate, is a rate calculated by a company's accountants that expresses the company's total expected overhead costs for a given period (usually a year) as a proportion of the expected direct costs over the same period. It is used to calculate the overhead recovery amount included in prices charged to customers (see Figure 5.1). There are differences between companies in the treatment of overhead costs, but a common method is to apportion the overhead costs as a percentage of direct labor costs. Overhead rates vary considerably from one company to another, perhaps from as low as 50 to as high as 200 per cent or even more. In a few cases contractors will apply different overhead rates to different projects (which can make life difficult for the accountants who attempt to set the general overhead rate). The rate used will depend on many factors that include the ratio of direct to indirect staff, the amount of internally funded R&D being done, local authority and public utility charges. Some customers for large projects use their purchasing power to insist on investigating and approving the overhead rates included in their project prices. High overhead rates increase prices and reduce the contractor's competitive advantage. If sales revenues exceed forecast, company overheads will be over recovered. Conversely, when times are bad and sales revenues fall below expectations, overheads will be under recovered. There is more on the control of overhead (indirect) costs in Chapter 24.

Prime cost—the sum of all the direct costs needed to fulfill a particular job or project (direct labor plus direct materials plus direct expenses).

Standard costing—an important and common accounting system in which cost estimates and actual project expenditure are calculated using average or

standard costs for direct labor and materials. These standards are calculated by cost accountants as expected averages for each grade of labor and for materials that are commonly held in stores and issued from general stock. Standard costs for materials are particularly relevant to manufacturing projects. Standard labor costs are important for most projects and they greatly simplify cost estimating. From time to time the accountants check the current standard labor cost rates against actual expenditure and they will issue revised standard rates whenever the variances become significant (usually as a result of cost inflation).

Variance—a term commonly used by accountants to describe the difference between actual costs and standard costs in a standard costing system. More widely, it is the amount by which any actual cost differs from its corresponding estimate or budget. Also used less commonly for the difference in time between an actual event and its planned time. Variances concentrate management attention on departures from budget or plan and are an essential component of *management by exception.*

Classification of Costs as Direct or Indirect

There are considerable differences between companies in the interpretation of direct and indirect costs. Sometimes the classification of costs as direct or indirect can vary even from project to project within the same company, depending on what each customer has agreed and contracted to pay for as a direct charge. To a large extent, the type of projects usually undertaken by a company and the industry in which the company operates will determine how the split between direct and indirect costs is made. For instance, professional people and companies such as consultants and attorneys often charge their clients for the costs of correspondence and telephone calls. Most other companies would regard those items as indirect costs to be recovered in the general overheads.

Cost estimators and project managers must be clear about the distinction between direct and indirect costs in their particular company. They must also be made aware of any exceptions to the rule caused by special terms in a project contract that allow the contractor to bill items directly that would normally classed as overheads.

ACCURACY OR RELIABILITY OF COST ESTIMATES

Estimating must start from some form of project specification, the preparation of which was outlined in Chapter 3. It is clear that the better the project can be defined at the outset, the less chance there should be of making estimating errors. However, the possibility of error can never be reduced to zero. No sensible person could ever declare the initial cost estimates for a total project to be entirely free from error and completely accurate. Estimating always involves an element of personal judgment. A project, because it is a new venture, must contain surprises and there will be many of those in large aviation projects. In some projects it might not even be possible to declare with confidence what the true costs actually were at the end of a project, owing to the complexities, errors and irregularities in cost collection, cost apportionment and cost accounting procedures.

In any but the very smallest project there will clearly be too many variables for any estimate to be confidently declared as 'accurate' or 'inaccurate' at the project start. Indeed, if the eventual final project costs did happen to equal the initial estimates that would be a matter for some congratulation and celebration but it would also be a matter of chance. Perhaps 'reliability' or 'degree of confidence' would be better measures of cost estimating performance.

Cost estimators must, of course, be aware of the difficulties, but they must not allow these to deflect them from their primary task, which must always be to use all the information and time available to produce the best estimate possible—in other words a calculated judgment of what the project *should* cost if all goes according to plan. Estimates made with a high degree of confidence will greatly assist those responsible for any competitive pricing decision, and good estimates improve the effectiveness of cost budgets and resource schedules.

Classification of Estimates According to Confidence in Their Reliability

Some companies find it useful to classify project cost estimates according to the degree of confidence that they deserve. These classifications depend on the quality of information available to the estimators, the time allowed for preparing the estimates and the stage reached in the project life cycle. They also depend, of course, upon the skill of the individual estimator, and we

shall discuss that topic later. Different organizations have their own ideas, but here is one example of a classification system used by an engineering company for its project cost estimates:

1. **Ballpark** describes estimates based on incomplete information, for example at the beginning of the project life cycle when only vague outline information about the project exists. Ballpark estimates are also made when time is too short for a more detailed estimate to be considered. An example is seen when a manager is shown a pile of manufacturing drawings and, weighing them carefully in the hand declares with unjustified confidence, 'There's two million dollars of cost here'. That could hardly be described as a reliable estimate yet there are a few of us who have an intuitive gift for making such cost predictions.

   Ballpark estimates are useful for preliminary checks on project resource requirements, for the initial screening of invitations from potential customers to tender for new projects and for other management decisions early in the project life cycle. A well-reasoned ballpark estimate might achieve an accuracy of ± 25 per cent, given a gifted estimator and generous amount of luck and good judgment. Far wider divergence can be expected. Ballpark estimates should clearly not be used as a basis for fixed-price tendering.

2. **Comparative estimates** are made by comparing new work to be done with similar work done on past projects. They can be attempted before detailed design work takes place, when there are no reliable materials lists or work schedules. They depend on a good outline project definition, which must enable the estimator to identify all the principal tasks and assess their degree of size and complexity. Another requirement is access to well-documented cost and technical archives from past projects, without which of course no comparisons could be made. Apart from commercial risks outside the estimator's control (foreign exchange rate fluctuations, for example), reliability will depend very much on the degree of confidence that can be placed in the proposed design solutions, on the working methods eventually chosen and on the closeness with which the new project tasks can be matched with those from the past. It might not be possible to achieve better than ±15 per cent accuracy.

Comparative estimates are commonly used as the basis for tenders in manufacturing and other engineering projects. When the time available for tendering is very short, contractors for construction projects may also be obliged to rely on comparative estimates, but they should then build in as many allowances for contingencies as competitive pricing will permit.

3. **Feasibility estimates** can be derived only after a significant amount of preliminary project design has been carried out. In construction projects, for example, the building specification, site data, provisional layouts and outline drawings for services are all necessary. Quotations must be obtained from potential suppliers of expensive project equipment or sub-contracts, and material takeoffs, bills of materials, parts lists or other schedules should be available to assist with estimating the costs of materials. The confidence factor for feasibility estimates should be better than ±10 per cent. This class of estimate is often used for by architects and construction companies for project tenders.

4. **Definitive estimates** cannot be made until most design work has been finished, all significant purchase orders have been placed at known prices and work on the project is well advanced or nearing completion. Definitive estimates can be produced from scratch, but the best practice is to arrive at them by continuously updating the original comparative or feasibility estimates as part of the project cost reporting and control procedure. Barring shocks or disasters during project execution, the accuracy of the total project estimate should improve as the project moves through its life cycle and the estimated costs are gradually replaced by their corresponding actual costs. Estimates can be labeled as ‘definitive’ when the time is reached where their accuracy is regarded as ±5 per cent or better of the final project cost. Unless the accounting and cost collection systems are flawed the definitive project estimate should converge on the actual project cost when all work on the project is done.

The degrees of reliability quoted in these examples are about as good could ever be expected. Some organizations will assign wider limits. It is also common to find asymmetric limits, slewed about zero. A company might, for example, work on the assumption that its ballpark estimates are accurate to within +50 or -10 per cent.

The Relationship Between Estimating Reliability, Pricing and Eventual Profitability

Reliable estimates are a valuable asset to managers faced with the difficult task of trying to price a project in the teeth of keen competition, where there is no scope for the luxury of safety factors such as a high mark-up on costs or the inclusion of big contingency allowances. The vulnerability of target profits to erosion from costs that exceed their estimates is not always appreciated. A simple example will illustrate this point.

Consider a project which was sold for a fixed price of $10 million against a total cost estimate of $8.5 million. The budgeted margin (gross profit) was therefore $1.5 million, which would be 15 per cent of the selling price. Now suppose that the project actually cost $9 million instead of the estimated $8.5 million. This would be regarded by some as a modest excess, and it represents a variance between estimated and actual costs of $500 000 or less than 6 per cent. Most estimators would be well pleased with such a close result and the managers of projects in the public eye that have cost over double their budgets would be delighted. However, this $500 000 reduction of gross profit represents a profit variance of 33.33 per cent. The intended profit has been reduced by one third. That is how this outcome would be viewed by the company's management and other stakeholders.

Planned profits can fall victim to many risks. Some of these can be predicted but others often come as unpleasant surprises. The aim must be to reduce the number of unknown variables or risks as far as possible, and then (if market competition allows) provide a sensible contingency sum to cover those that remain.

Managing a project that has been underestimated can be a soul-destroying experience, with everything running late, everyone demoralized and all remaining cost predictions made only for the purpose of assessing the size of the impending loss. Project managers who have presided over this depressing state of affairs would not wish to repeat the experience. If they were in any way responsible they may not be given the chance.

TOP-DOWN OR BOTTOM-UP?

There are two fundamentally opposite ways of approaching cost estimating for a large project. The approach taken depends upon the time available, the degree of reliability expected and, above all, the level of project definition available.

Top-down Estimating

Very early in the project life cycle only outline proposals for the nature and scope of the project exist to guide the cost estimator. No detailed task list or comprehensive work breakdown is possible at that early stage. Thus preliminary cost estimates can be made only on a global comparative basis. That means trying to assess the cost of the project in its entirety by comparing it with similar projects completed in the recent past for which actual cost records are available. If the project can be divided into a few major parts at this early stage, it should be possible to distribute the total estimate over those parts, remembering to leave something in reserve in the form of a separate contingency item. However all these estimates originate from considering the whole, or top of the project, which is why this approach is called top-down.

It is apparent that top-down estimates must usually be ballpark. They have the disadvantage of not being based on a detailed project specification. They cannot take into account many factors that will not become known until much later in the project life cycle and their inherent accuracy will not be high. However, because top-down estimates are often based on comparisons with entire completed projects, there is less risk (when compared with bottom-up estimating) of forgetting to include items and thus arriving at dangerously low estimates.

Bottom-up Estimating

The opposite extreme to the top-down approach is bottom-up estimating. This method can only take place when a good project specification exists and a fairly complete task list has been compiled. Bottom-up estimating begins at the lowest level of detail, and is gradually extended up through the hierarchical structure of the project, building up the figures until the total estimated project cost is reached at the top of the tree.

Because bottom-up estimates are made later in the project life cycle, when more is known about the project, they should be more reliable than top-down estimates. However, bottom-up estimates can be more prone to errors of omission than top-down estimates (in cases of not seeing the wood for the trees).

The methods that follow in this chapter are based on bottom-up estimating and they all depend upon starting from a task list or, better still, a work breakdown structure (WBS).

COMPILING THE PROJECT TASK LIST FOR BOTTOM-UP ESTIMATES

The first stage in the bottom-up cost estimating process is to compile a complete list of every known item that is going to cost money. This can prove difficult. But any item inadvertently left out of the cost estimates must obviously result in an underestimate. That could jeopardize planning and scheduling and (if not realized in time) lead to serious problems and red faces when the time comes to hand the project over to the customer. And, of course, if the project has been sold for a fixed price, any items forgotten by the estimator must be paid for not out of the budgeted project funds, but from the contractor's expected profits.

Estimating Difficulties Owing to Lack of Information Early in the Project Life Cycle

Unfortunately provisional cost estimates are usually needed during the early project definition stages when many cost items will be unknown or ill-defined. It would be impossible to compile a detailed list of all the components, assemblies and equipment in sufficient detail for bottom-up estimating.

In Chapters 10 and 11 we explain cost and work breakdown methods, some of which would be invaluable to the early cost estimator. However, whilst a detailed WBS is the ideal framework for a project cost estimate, in practice the earliest estimates will have to be compiled from a simple list of the major known tasks or, at best, a rudimentary form of the WBS. A great

degree of skill and judgment is therefore necessary in these early project cost estimates and there is plenty of scope for errors.

A Simplified WBS as a Starting Point for Bottom-up Cost Estimating

Preparation of a WBS is a logical way of considering the work (and then the costs) required for a project. Its principal value in cost estimating is that it allows all the cost items to be set out in their logical hierarchy within the project. It will reduce the risk of forgetting to include significant items in the cost estimates. Although a detailed WBS cannot usually be produced in time for the early cost estimators, a rudimentary work breakdown diagram can often be produced that the cost estimators should find invaluable.

Suppose, for example, that we are embarking upon a new aircraft development project with every part designed new from the ground up. Produce an outline sketch of the aircraft, add some expected performance figures and you can rest assured that the cost estimator would be facing a very difficult task. However, break that project down into smaller pieces, ask for these to be estimated one at a time, and the estimator will feel a little more comfortable and better able to make judgments on the possible costs. The simple example of a WBS in Figure 5.2 would need expansion for managing the project, but it is a far better starting point for the estimator than a simple sketch of the whole aircraft. The numbers in the boxes are cost codes that represent each part of the breakdown and fit in numerically with the hierarchical schemes.

Using Checklists

One very useful way of helping to omit tasks from the estimate is to use checklists, such as those used for early project definition (described in Chapter 3). Every company with sufficient experience can develop these. A full checklist would include all possible factors—technical, commercial, statutory, environmental, social and so on—that might eventually have a bearing on the work and its costs.

Some checklists can be long and detailed documents. Typically they will list as many possibilities as the compiler can think up, so that they must inevitably include some irrelevancies and seem tedious to use. It is,

however, in this very wealth of detail that the importance and strength of checklists lies.

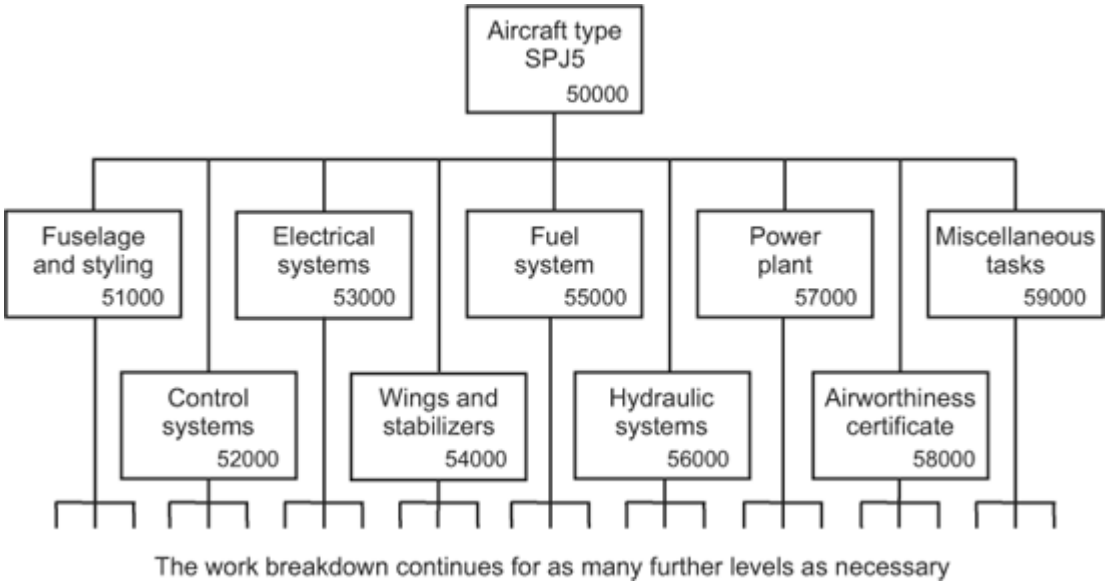


Figure 5.2 The upper levels of an aviation project work breakdown

Software Tasks

The project task list must include not only all the obvious items of project hardware, but also every associated software job. Software is a familiar term in the context of computers and IT projects, but most projects quite remote from computer work have their own software content. Schedules for production inspection and testing, instruction and maintenance manuals, lists of recommended spares and consumable items may have to be specially written. These, together with any other documentation specified in the proposal or contract, are software tasks which must usually be allowed for in the estimated costs.

Forgotten Tasks

Activities often forgotten during the estimating phase of manufacturing projects, only to be remembered too late for inclusion in the project budgets (and prices), include incidental processes such as paint spraying, heat treatments, inspection and testing. In some firms these may be covered by the general overhead rate, but in many others they will not and must be listed

among the direct cost estimates. Protective plating, silk-screen printing, engraving and so on are frequently omitted from estimates.

A more serious omission from project cost estimates is the work entailed in final commissioning, handover and customer acceptance of the completed project. For airplane development that can mean a prolonged program of expensive test flights, each of which must be followed by analysis of the results and, where necessary, modifications or adjustments to the aircraft.

Contracts often require the project contractor to provide training facilities for some of the customer's staff. The manufacturer of a complex and special machine might be expected, for example, to install the machine and supervise its start-up by training the customer's operatives and maintenance technicians. Training sessions can involve the contractor's senior engineers in much hard work, both in the actual training and in preparing the training manuals beforehand. Incidental expenses may also arise for accommodation and meals, depending on where the training is to be carried out.

Whether the proposal is for aviation equipment, a large airport construction project, management change or an IT project, the business of filling as many gaps as possible in the task list is a continuous aspect of project definition. The project specification might have to be revised and reissued more than once as the task list is developed.

Level of Detail in Project Cost Estimating

Some difficulty might be experienced in deciding how much detail to show in the task list. What is a 'task' for this purpose?

Consider, for instance, the problem of estimating the total cost of a project for designing and manufacturing a major aircraft component in readiness for preparing a fixed-price proposal. Suppose further that this component is an assembly of mechanical and electrical components. The cost estimate must often be made before any detailed design has taken place, and therefore with only sketches or provisional layout designs. It will not be possible to list all the manufacturing operations or the raw materials needed for each separate part. It will not even be known at this early stage what or how many parts are going to be needed. Therefore this initial cost estimate, even though it might contribute to a fixed-price commitment, can only be carried out on a much broader scale than estimates for run-of-the-mill manufacturing.

Each task should be selected so that it is small enough to be visualized easily for estimating purposes. On the other hand, the task must be large enough to represent a measurable and significant part of the whole project. The design and manufacture of each sub-assembly from a main piece of equipment might rank as a task, while the final assembly of all these sub-assemblies could be regarded as another.

An example that applies to many kinds of projects is the writing, editing and printing of an instruction manual or an operating and maintenance manual. These are items that should be set out as definite tasks. Separately identifiable purchases of expensive bought-out components and equipment should also be listed, where these are not already included in other tasks. Any special requirement for packing and dispatch of the final project might have to be listed as a task, particularly if the project has to be shipped in export packaging to an overseas customer.

Every one of the examples just given is an identifiable and specific part of the project, chosen at a level intended to make the job of estimating easier and more reliable. Careful identification of all significant tasks at this stage, in addition to the obvious importance for cost estimating, will provide a basis for budgeting, scheduling and subsequent control.

DOCUMENTING THE COST ESTIMATES

When the cost estimates have been made and collected they will contain a large amount of data. These data should be presented in a format that will allow easy reference, detailed analysis and extension into total amounts—whether for departmental costs or for packages at any level of the project work breakdown. Therefore, a certain amount of procedural discipline has to be imposed on the estimating function throughout the organization, and from one project to another. Estimates should be tabulated according to a standard company procedure and itemized where possible by cost codes within the WBS (see Chapter 10). This will help to ensure that comparisons can readily be made later in the project life history between the estimates and the cost accountant's records of the actual costs eventually incurred, on a strict item for item basis. This is essential as part of the cost control function. As experience builds up over a few years and more data are collected it will also contribute to the accuracy of comparative estimates for new projects.

If no WBS exists, and the initial cost estimate is simply set out like a shopping list, it should be reorganized into a hierarchical work breakdown format as soon as the project's WBS becomes known.

Some cost estimates, especially those for defense and other national government projects, may be liable to investigation by external auditors at one or more stages. These investigations can be exhaustive and taken into considerable detail. Paying careful attention to logic and detail in presenting the cost estimates can help to establish the good relations necessary for reaching a fair agreement.

Observance of company policy on cost rates and costing methods, as well as the need to determine working budgets, imposes an obligation on the project manager to ensure that the estimates are set down in a standard and logical manner. Calculations performed in odd corners of notebooks, on scraps of paper, and on the backs (or fronts) of envelopes are prone to error and premature loss. They will be unlikely to fulfill any of the conditions already mentioned. In other words, standardized estimating formats are needed (either as hard copy or as forms on a computer).

Estimating forms are usually spreadsheets. A large project will need many such sheets, and they should be compiled in sets and subsets that reflect the anatomy of the whole project. The WBS is the ideal model, where such exists. WBS design and coding principles were demonstrated in Figure 5.2 and are described more thoroughly in Chapter 10. Every task within the WBS should be given a cost code and the coding system should be structured to agree with the hierarchical WBS system.

WBS codes are essential for sorting and retrieving not only the estimates, but also their eventual corresponding actual costs. A computer database could not operate without a logical coding arrangement. Codes will allow the cost estimate for any item to be estimated and filed in a place from which it can easily be retrieved later. The coding structure will also facilitate any calculations that require various permutations and combinations of the cost estimates, for example to group costs by a particular sub-assembly, department or labor grade.

A General Purpose Cost Estimating Form

An example of a general purpose estimating tabulation is given in Figure 5.3. This design is based on a form used by several divisions of an international

company for projects ranging from airfield-based automatic test equipment for military aircraft to prefabricated hospital operating theatres. All these projects, although very different in design and work content, shared the typical project characteristic of requiring many components and sub-assemblies that each needed engineering design, purchase of materials and components followed by manufacture.

The general purpose format in Figure 5.3 allows for six labor grades to be shown and assumes that all hours will be costed at standard cost rates. Six grades should be adequate, provided that the standard costing system has been designed sensibly and has not been complicated by interference from the 'wouldn't it be nice if…' brigade. The standard grade code and cost rate used should be entered in the space at the head of each column to show the rates that were current at the time of estimating.

There is no need to complicate a general purpose estimating form by adding columns for such things as special tooling. Such items can easily be accommodated by considering each as a separate task in its own right. Each can be entered on a row, and the costs added up along the row in the same way as for any other task.

The inclusion of a column headed 'longest lead-time' in the materials section might appear unusual in a form intended primarily for cost estimating. However, the people who estimate material costs are also the people most probably able to predict delivery times. It is convenient and more efficient to collect both sets of data from them as early as possible and on the same occasion. This extends the usefulness of these forms by enabling their use as a valuable information source for subsequent timescale planning.

An Estimating Form for Equipment and Materials Purchases on Larger Projects

In larger projects, general all-purpose forms are inadequate for listing all the cost estimate considerations for buying-in materials, components and equipment.

Estimates for many of the bulk materials used in construction projects are often made on very detailed schedules or material 'takeoffs' which are specially designed for each of the particular engineering disciplines involved (such as piping takeoffs compiled by fluids engineers and steel takeoffs worked out by the civil and structural engineers). However, the form shown

in Figure 5.4 can be used for listing the cost estimates for significant items of equipment or other high-cost purchases required for a project. Provision is made on this form for including freight and duty costs, which are of course especially relevant when the delivery site is distant or overseas from the source of supply. Totals or convenient subtotals from materials takeoffs and other materials schedules can be transferred to this type of form to allow the complete project materials costs to be summarized and totaled.

A General Purpose Project Cost and Price Summary Format

The format in Figure 5.5 can be used in some cases to summarize project cost estimates and assist in pricing small projects. This form has been designed for general purpose flexibility, for use over a wide range of different small projects. Although spaces for various rates, allowances and mark-ups are provided, the way in which these are used can be chosen to fit in with a particular company's management and accounting requirements. The form allows the actual figures and formula used in the cost/pricing relationship to be recorded but it does not dictate the pricing mechanism too rigidly, because the price must usually be considered by senior management according to the merits of each case.

COST ESTIMATE

Project number or sales reference:

Estimate number:
Case:
Date:
Page of

Estimate for:

Compiled by:

1	2	3	4		5		6		7		8		9		10	11	12	13	14	15
Code	Item description	Qty	Labor times and costs by standard grade												Total direct labor cost	Overhead cost %	Materials			Total cost 10+11 +12+13
			Grade 1		Grade 2		Grade 3		Grade 4		Grade 5		Grade 6				Standard or net cost	Burden %	Longest delivery (weeks)	
			Hrs	$	Hrs	$	Hrs	$	Hrs	$	Hrs	$	Hrs	$						

Figure 5.3 A useful format for general cost estimating purposes

COST ESTIMATE FOR MATERIALS AND PURCHASED EQUIPMENT

Project number or sales reference:

Estimate number:
Case:
Date:
Page of

Estimate for:

Compiled by:

Cost code	Description	Spec. No (If known)	Proposed supplier	Unit	Unit cost F.O.B.	Quoted currency	Exchange rate used	Converted FOB cost	Qty	Project FOB cost	Ship mode	Freight Cost	Taxes/ duties	Delivered cost
Total delivered materials and equipment costs this page →														

Figure 5.4 A format for estimating the costs of materials and bought-out equipment on larger projects

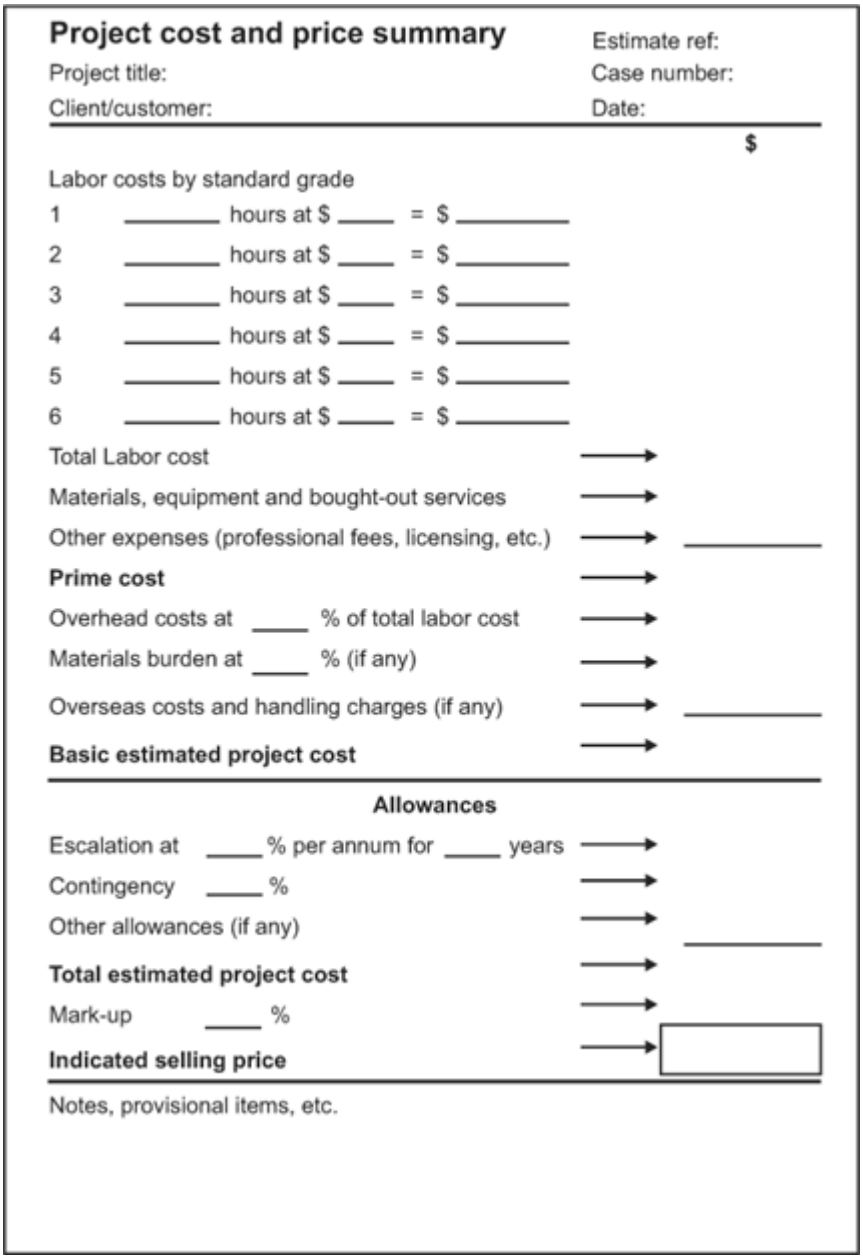

Project cost and price summary
Estimate ref:
Project title:
Case number:
Client/customer:
Date:
$
Labor costs by standard grade
1 _____ hours at $ ____ = $ _____
2 _____ hours at $ ____ = $ _____
3 _____ hours at $ ____ = $ _____
4 _____ hours at $ ____ = $ _____
5 _____ hours at $ ____ = $ _____
6 _____ hours at $ ____ = $ _____
Total Labor cost
Materials, equipment and bought-out services
Other expenses (professional fees, licensing, etc.)
Prime cost
Overhead costs at ____ % of total labor cost
Materials burden at ____ % (if any)
Overseas costs and handling charges (if any)
Basic estimated project cost
Allowances
Escalation at ____ % per annum for ____ years
Contingency ____ %
Other allowances (if any)
Total estimated project cost
Mark-up ____ %
Indicated selling price
Notes, provisional items, etc.

Figure 5.5 A general purpose format for indicating the price of a small project

A Project Cost Estimate Laid Out According to the Project WBS

Cost estimates for larger projects should be set out to agree with the project WBS (or cost breakdown structure). There are many different ways in which this can be done, but an example is given in Figure 5.6. This case is relevant to the aircraft development project mentioned earlier, with the WBS shown

in Figure 5.2. All the cost values are for demonstration only and are not intended to bear any relationship to the costs of an actual project.

Cost estimate summary for the SPJ5 project

Compiled by: Dennis Lock — Revision 2, 1 April 2010

			$	$
51000	Fuselage and styling			1 696 000
		Design labor	550 000	
		Shop labor	376 000	
		Materials	760 000	
		Expenses	10 000	
52000	Control systems			1 353 000
		Design labor	265 000	
		Shop labor	423 000	
		Materials	630 000	
		Expenses	35 000	
53000	Electrical systems (includes avionics)			2 133 000
		Design labor	344 000	
		Shop labor	541 000	
		Materials	1 213 000	
		Expenses	35 000	
54000	Wings and stabilizers			1 460 000
		Design labor	603 000	
		Shop labor	415 000	
		Materials	422 000	
		Expenses	20 000	
55000	Fuel system			699 000
		Design labor	196 000	
		Shop labor	45 000	
		Materials	433 000	
		Expenses	25 000	
56000	Hydraulic systems			644 000
		Design labor	245 000	
		Shop labor	313 000	
		Materials	66 000	
		Expenses	20 000	
57000	Power plant (engines bought in from P and W)			4 827 000
		Design labor	152 000	
		Shop labor	350 000	
		Materials	4 250 000	
		Expenses	75 000	

58000	Airworthiness certificate (includes proving flights)		1 010 000
	Design labor and aircrew	320 000	
	Shop labor	105 000	
	Materials/fuel	60 000	
	Expenses	525 000	
59000	Miscellaneous tasks (includes hangar equipment)		705 000
	Design labor	73 000	
	Shop labor	80 000	
	Materials	532 000	
	Expenses	20 000	
50000	Total estimated project cost (2 prototypes)		14 527 000
	Design labor	2 748 000	
	Shop labor	2 648 000	
	Materials	8 366 000	
	Expenses	765 000	

All costs shown above are fictitious and are shown here only to demonstrate the layout

Figure 5.6 A project cost estimate set out by WBS

ESTIMATING MANUFACTURING COSTS

Manufacturing organizations prefer to use drawings and parts lists or bills of material as the basis for making cost estimates. Those documents allow accurate estimation of the raw materials and components needed, and production engineers can work out the operations needed to make the parts and estimate labor-times from those. Several common key factors can be identified in the use of routine methods. Work is always broken down into small elements before estimates are applied. The estimates themselves can usually be described as ‘standard’ or ‘known’ quantities, and any need for guesswork is either eliminated or reduced to a minimum. Reliance is placed not on personal opinions of how long each job should take, but on the results of long experience, detailed analysis and scientific work measurement.

Estimating Manufacturing Costs Without Detailed Drawings

Project cost estimating is usually quite different from routine manufacturing estimating because the estimates must be made long before detailed drawings exist. Suppose that an estimate is to be prepared for a control unit. This is a box that will be filled with instrumentation. However, detailed design has yet to take place and manufacturing drawings do not exist. Only one box of this special type is to be made, for use on the particular project. The only information on which a cost estimate can be based is an engineer’s written design specification. This specification includes little or no information

about dimensions, materials or the contents of the box. It simply states the functional performance expected of the completed product in terms of its input and output parameters and its planned operating environment. If the estimator is very lucky, there might be a rough outline sketch of the box.

Standard estimating tables will be of little help here. Build up of time and cost standards depends upon the establishment of production continuity, which demands in turn that a certain minimum volume of production must take place. Such standards cannot be applied to 'one-off' production, where unknown variables dominate the picture. In any case, there are no drawings from which to break the work down into its constituent operations, so there is no hope of using standard estimates.

A stage in the project preparation and planning process has now been reached where many professional estimators, production engineers and work study devotees find themselves floundering well out of their normal depth. Their trusted records of standard times, with which they have worked for many years, and much of their professional training will be virtually useless when they are faced with the problem of estimating for work where no drawings exist. Drawings and parts lists are the customary means of expression and communication for these people. Without such aids they are rendered helpless. They feel deprived and will be unwilling to commit themselves to forecasts that they might be called upon to justify later.

Project cost estimating is not made any easier by the short time usually available. All too often a tender has to be prepared within a few days if it is to meet the deadline set by a prospective customer. Failure to meet the closing date could mean that the proposal is automatically disqualified, with the order irrevocably lost to a competitor. Within the short time available, cost estimates might have to be made for a large number of items. The project might need, for example, hundreds of control units, all different and all to be manufactured singly. Even if drawings could be found, there would be insufficient time to analyze these for detailed cost estimating.

The job of cost estimating can itself be expensive. It is easy to spend a great deal of time and money in the process, especially where there is no pressure to produce the estimates quickly. Low probability of obtaining a project order might not justify much expenditure on estimating and tender preparation.

Project estimating, as has already been seen, is carried out on a much broader scale that run-of-the-mill production work. In the absence of detailed

information, larger work packages must be visualized. The only people capable of taking this broader view are likely to be the more senior members of the organization. Departmental managers often become involved, if not in making the estimates at least in approving them. For project manufacturing estimates, therefore, input will probably be needed from production management.

There is no simple solution to all these problems, but it is possible to outline an approach that can yield acceptable results. Fortunately the lack of drawings and the need for making estimates in a short space of time are both conditions that demand a similar estimating technique.

Within the context of our simple example of a control unit (a small metal box filled with instrumentation) the estimating method might proceed along the following lines. First, a description of the proposed box is needed, with some idea of its likely contents. The design engineers must provide this information, because they are the only people at this early stage who can possibly have any real idea what the final, assembled box will be like.

Once a description of the box has been set down it is usually possible to scan the archives to find a previous piece of work which bears some resemblance to the new job. Classification and coding of past work and cost records can be a great help when it comes to making such a search. Once again it is only the design engineers who can be asked to draw useful comparisons at this early stage. It might well be found that no direct parallel exists but that a previous similar job was carried out which was somewhat simpler than the present object of concern. 'How much simpler?' is the question that must now be asked. The engineer might say that about ten per cent more components will be needed this time, giving a basis on which the production department can make a comparative estimate.

When the records of actual expenditure on the previous box have been looked up, the production supervisor or production manager can reasonably be expected to make an estimate for the new work, given the information that about ten per cent more components will have to be accommodated and assembled. If the old box took one labor-week to fabricate, this might be considered a good enough estimate for the new sheet metal operations. Only a couple more holes are going to be needed to fix the extra components. Wiring and piping must take longer, however, since the ten per cent increase in the number of components must result in a corresponding increase in the number of connections to be made. A previously recorded assembly time of

two labor-weeks might therefore be extended to give an estimate of two and a half labor-weeks for the slightly more complex box.

These comparative estimates can never, of course, be considered or expressed in fine units of time. Labor-weeks or labor-hours are the usual choices. Using anything less (man-minutes, for example) would expose the cost estimator to the same trap as the scientist who carries out research using data and measurements accurate to no better than one or two per cent, but then has the temerity to express the final results using long strings of decimal places.

Once the idea has been accepted that production time estimates have to be seen in broad terms, on a scale that equates with packages in the work breakdown, they can be collected and collated in exactly the same way as estimates for design engineering and other non-manufacturing project activities. The estimating system can therefore be standardized, with all cost predictions collected according to the same set of rules and using a common estimating form.

ESTIMATING PROJECT LABOR COSTS

The Application of Standard Costing to Labor-cost Estimates

Standard costs make the life of the cost estimator relatively easy, because there is no need to consider differences in wages or salaries paid to different people of equivalent staff grade. The cost estimator cannot possibly name the individuals who will be engaged on jobs that might not be started for months, even years after the estimates are made. Also, the use of standard labor cost rates means that the wages and salaries paid to individuals can be kept confidential.

For a standard costing system, the first step in determining standard labor cost rates is to classify people according to some convenient rules (usually based on a combination of the work that they do and their general level in the salary structure). Categories which one international company found suitable for its home office engineering and clerical staff are listed below. These six grades were found to be sufficient even for large capital projects involving engineering, purchasing and construction:

Grade 1—company directors, divisional managers and professional staff of consultant rank.

Grade 2—departmental managers and the chief engineers of specialist engineering groups.

Grade 3—project engineers and senior engineers in all the specialist engineering disciplines.

Grade 4—engineers in all the specialist disciplines.

Grade 5—drawing office group leaders and checkers.

Grade 6—draughtsmen and women plus all clerical and general administrative staff except managers.

It is best if the number of standard grades can be kept to a minimum (fewer than ten). The accountants work out an average salary cost (the standard cost) for those in each grade. All estimates and actual jobs are then costed using these grades and standard rates.

Because the standards are calculated within the confines of the accounts department, the method has the advantage of preserving the confidentiality of individuals' earnings: cost estimators and project administration staff need only be told the current standard rates. However, these standard rates should still be treated as confidential proprietary information because they might be of use to competitors.

Using and Archiving Labor-times Rather Than Labor Costs

Generally speaking, while wages and their related standard cost rates change from year to year, the time needed to carry out any particular job by a given method should not. Work-time is therefore regarded as the fundamental basis for labor-cost estimates. Conversion from labor-hours to money can only be regarded as a derivative, secondary process which is dependent on factors and other influences that change costs with the passage of time. Comparative estimates for labor should be made by comparing labor-hours or other time units, not costs, from records of past projects.

Responsibility for Estimating Labor-times

In project work there is a shift of emphasis compared with routine manufacturing cost estimating, where detailed estimates could safely be entrusted to an individual or a group specializing only in cost estimating or production engineering. Wherever possible, estimates for project labor-times should be obtained from managers or senior individuals of the departments that are going to be responsible for carrying out the project tasks later. It would be reasonable, for example, to expect the chief design engineer to provide the design engineering estimates.

Decentralizing the estimating function in this way reflects the change in scale when progressing from production estimating to project work. It is not done simply to gain a more accurate estimate of project costs, although that is usually the prime reason. When a large project is being planned, the labor-time estimates can have a profound influence on the staffing budgets for years to come. Any departmental budget, whatever the type of work involved, should be more realistic and achievable if the departmental manager has either produced or fully agreed the cost estimates on which the budget (and the manager's future commitments) is based.

Collecting Estimates for Labor-times

If the labor estimates for a project are to be obtained from a number of different departmental managers or their senior representatives, it follows that the set of project estimating forms must be circulated among all the participating departments. This can be done in several ways, with varying degrees of effectiveness.

The first proposition is that one master set of forms could be assembled, attached to a circulation list and sent to the department that is first on the list. That department would be expected to enter its estimates and pass the set of forms on to the next-listed department until, all the estimates having been completed, the bundle should arrive back on the project manager's or proposals manager's desk. Everyone knows how long a library copy of a magazine takes to complete its circulation and of the risks that it faces on its journey—it might never be returned to the library at all. For the same reasons the circulation method can be dismissed as impracticable for collecting project estimates.

A second possibility is to prepare a set of pre-headed estimating forms for each department and send them all out simultaneously, either as hard copy or

over a computer network. This has the advantage of cutting out the serial delays of the first proposition but it still relies on the wholehearted cooperation of all the departmental heads. Late input can be expected, while it is known from bitter experience that some hard-copy sets might even be lost altogether.

Estimating is often regarded as an unpleasant task, a chore to be avoided at all costs if other priorities can be found as an excuse. Therefore no one can expect to rely solely upon polite requests for data to be provided on blank estimating forms. A more direct approach is sometimes needed.

Another way in which to collect the estimates would be to ask for them during early project planning meetings and complete a set of estimating sheets on the spot. This occasion provides the opportunity, since all key project members should be on hand. This approach might be considered for very small projects but there are at least four snags:

1. Network planning estimates are always made principally for individual task durations (for total elapsed time) rather than for their work content in labor-hours. However, some form of work content estimates are made at planning meetings in addition to the task duration estimates if the plans are to be the basis of subsequent resource scheduling.
2. Project planning meetings can involve much effort and take considerable time—perhaps needing more than one session of several hours. Protracted meetings do not produce the best results and it is wise to avoid asking too much of the members. The law of diminishing returns can apply when any meeting exceeds about two hours. Members will start to fidget, want to get back to their departments to sort out more pressing problems or go home.
3. Material costs are not usually considered at project planning meetings. A separate estimate collection exercise for material costs would therefore be needed in most cases.
4. Perhaps the most important problem of all is that detailed project planning and scheduling sessions are likely to take place far later than the time when the cost estimates are needed for the project proposal or tender.

Short of applying legal compulsion or threat of physical violence, personal canvassing is the best way to get quick and dependable results. The process starts by preparing a complete set of estimating sheets for the project, on which every known task is listed and cost coded. If a WBS exists,

the sheets should be arranged in logical subsets as illustrated in Figure 5.6. The project manager (or delegate) can then embark on a tour of all the departments involved, arriving purposefully at each manager's desk in turn. This applies even if the estimating forms have been set up in a computer. The aim is to remain firmly rooted in each department until all the desired data have been entered on the forms or in the computer system. The person performing this task may become unpopular in the process, but becoming well-liked is not the most important aspect of a project manager's job.

Canvassing affords the project manager or proposals manager an opportunity to assess the estimating capabilities of all the individuals concerned. Any estimate which appears unrealistic or outrageous can be questioned on the spot, and many other details can be sorted out with the least possible fuss and delay. One type of question which must frequently be asked of the estimator takes the form: 'Here is a job said to require four labor-weeks; can four people do it in one week, or must the job be spread over four weeks of elapsed time with only one person able to work on it?' The answers to such questions are of obvious importance in scheduling time and resources, of which more will be said in later chapters.

Production staff often need help in their project estimating task. If an engineer collects the estimates, he or she can often supply this help by explaining the design specification in terms that production people can understand. Similarities with past projects can be suggested and any artists' impressions or other sketches that might be available can be shown and amplified by verbal description.

ESTIMATES FOR MATERIAL AND EQUIPMENT COSTS

Materials always need two types of estimate. For each purchase these are as follows:

1. The total expected cost, including all charges and taxes payable in transporting the materials to the project location.
2. The total lead-time, which is the time expected to elapse between issuing the purchase order and receiving the consignment (failure to get materials on time is a common cause of delays and late project completion).

It might also be necessary to make estimates of other factors for operational purposes; for example the volume or weight of materials (information needed for storage and handling).

If detailed design has yet to be carried out, no parts lists, bills of materials or other schedules will exist from which to start the estimating process. Therefore the next best approach is to ask the engineers to prepare provisional lists of materials for each task. This may be impossible to carry out in detail, but the problem is not as difficult as it would first seem. In most work the engineers have a very good idea of the more significant and most expensive items that will have to be purchased. There might be special components, instruments, control gear, bearings, heavy weldments or castings, all depending of course on the type of project. Items such as these can account for a high proportion of the costs and are frequently those which take the longest time to obtain. In construction projects outline assumptions can be made for the types and quantities of bulk materials needed.

Foreknowledge of these main, most expensive items of expense reduces the unknown area of estimating and therefore improves the forecasting accuracy. If all the important items can be listed and priced, the remaining miscellaneous purchases can be estimated by intelligent guesswork. Records of past projects can be consulted to help assess the probable magnitude of the unknown element. If, for example, the known main components are going to account for 50 per cent of the total material costs, an error of ten per cent in estimating the cost of the other materials would amount only to 5 per cent of the total. It is most important, however, to prepare the list of known items very carefully, ensuring that the job is done conscientiously and without serious omissions.

The purchasing department or purchasing agent should be involved, and estimates for prices and delivery times must be obtained through their efforts whenever possible. If the purchasing organization is not allowed to partake in preparing the detailed estimates, a danger exists that when the time eventually comes to order the goods these will be obtained from the wrong suppliers at the wrong prices. It is far better if the big items of expense can be priced by quotations from the anticipated suppliers. The buyer can file all such quotations away in readiness for the time when the project becomes live. If the purchasing department is to be held down to a project materials budget, then it is only reasonable that they should play the leading role in producing the material estimates.

The responsibility for estimating materials, therefore, lies in two areas. The engineers or other design representatives must specify what materials are going to be used. The purchasing department should be expected to find out how much those materials will cost and how long they will take to obtain.

Any estimate for materials is not complete unless all the costs of packing, transport, insurance, port duties, taxes and handling have been taken into account (see, for example, the reference to Incoterms in Chapter 19). The intending purchaser must be clear on what the price includes, and allowances must be made to take care of any services that are needed but not included in the quoted price.

Another cautionary word concerns the period of validity for quotations received from potential suppliers. Project cost estimates are often made many months—even years—before a contract is eventually awarded. Suppliers' quotations are typically valid for only 90 days or even less, so that there could be a problem with the materials cost budget or the availability of goods when the time eventually arrives for the purchase orders to be placed.

PERSONAL ESTIMATING CHARACTERISTICS

Project cost estimating is never an exact science. Much of the process, particularly when estimating labor-times, has to rely on the subjective judgment of individuals. If any ten people were to be asked separately to judge the time needed for a particular project task, it is hardly conceivable that ten identical answers would be received. Ask these same ten people to estimate the times for a large number of different project tasks, and a pattern should emerge when the results are analyzed. Some people will tend always to estimate on the low side. Others might give answers that are consistently high. The person collecting project cost estimates needs to be aware of this problem. In fact, just as it is possible to classify estimates according to confidence in their accuracy, so it is possible to classify the estimators themselves.

Optimistic Estimators

As a general rule it can be taken that estimates for any work will more frequently be understated than overstated. Many people seem to be blessed

with an unquenchable spirit of optimism when asked to predict completion times for any specific task. 'I can polish off that little job in three days,' it is often claimed, but three weeks later the only things produced are excuses. Without such optimism the world might be a much duller place in which to live and work, but the project manager's lot would be far easier.

An interesting feature of optimistic estimators is the way in which they allow their Cloud-cuckoo-land dreams to persist, even after seeing several jobs completed in double the times that they originally forecast. They continue to churn out estimates which are every bit as hopeful as the last, and appear quite unable to learn from their previous experience. Fortunately the 'ill wind' proverb holds good here, with the wind in this case blowing to the good of the project manager. The source of consolation in analyzing such estimates lies in the fact that they are at least consistent in their trend. Shrewd project managers will come to learn by experience just how pronounced the trend is in their own particular company. Better still, they will be able to apportion error factors to particular individuals. A typical multiplication factor is 1.5. In other words it is often necessary to add about 50 per cent to the original estimates.

Pessimistic Estimators

Occasionally another kind of individual is encountered who, unlike the optimist of more customary experience, can be relied upon to overestimate most tasks. This characteristic is not particularly common and, when seen, it might pay to investigate the underlying cause. Possibly the estimator lacks experience or is incompetent. These explanations are unlikely, since the typical symptom of estimating incompetence is random behavior and not a consistent error trend.

The picture becomes clearer, if more unsavory, when it is remembered that project estimates play a large part in determining total departmental budgets. Higher project estimates mean (if they are accepted) bigger budgets for costs and manpower, and thus expanding departments. This in turn adds to the power and status of the departmental heads. In these cases, therefore, 'E' stands not only for 'estimator' but also for 'empire builder'. Correction factors are possible, but action is more effective when it is aimed not at the estimates but at their originators.

Inconsistent Estimators

The inconsistent estimator is the universal bane of the project manager's existence. Here we find a person who is seemingly incapable of estimating any job at all, giving answers that range over the whole spectrum from ridiculous pessimism to ludicrous optimism. The only characteristic reliably displayed is inconsistency. Incompetence or inexperience suggest themselves as the most likely causes. Complacency could be another. People looking forward to retirement rather than promotion, and staff who were overlooked during the last round of promotions can display these symptoms.

Unfortunately this category can manifest itself at departmental head level —precisely the people most frequently asked to provide estimates. Only time can solve this problem.

Accurate Estimators

It has to be allowed that there is a possibility, however remote, of finding a manager capable of providing estimates that are proved to be consistently accurate when the work actually takes place. This contingency is so remote that it can almost be discounted. When this rare phenomenon does occur it is apt to produce a very unsettling effect on the work-hardened project manager who has, through long experience, learned that it pays always to question every report received and never to take any forecast at its face value.

Making Allowances

Why should we not try to educate the estimators? Prevention, after all, is better than cure. But the results of such a re-education program must be unpredictable, with the effects varying from person to person, upsetting the previous equilibrium. In any case, all of the estimators could be expected to slip back into their old ways eventually and, during the process, their estimating bias could lie anywhere on the scale between extreme optimism and pessimism. Arguing wastes time if nothing is achieved. Accept the situation as it exists and be grateful that it is at least predictable.

Here, then, is a picture of a project manager or proposals manager obtaining a set of estimates for a project, sitting down with a list of all the estimators who were involved, complete with the correction factor deemed

appropriate for each individual, and then factoring the original estimates accordingly. Far fetched? The value of this procedure has been proved in practice.

REVIEWING THE COST ESTIMATES

When all the detailed estimates have been made it should, theoretically, be possible to add them all up and produce a bottom-up forecast of the whole project cost. When this stage has been reached, however, it is never a bad plan to stand well back for a while and view the picture from a wider angle. Perhaps a top-down estimate of the project might be made for comparison. Or, as a particularly valuable exercise, try converting the figures for labor-times from hours into labor-years.

Suppose that the engineering design work needed for a project appears to need 8225 labor-hours or 235 labor-weeks (according to which units were used). Assume that 1645 labor-hours or 47 labor-weeks are roughly equivalent to one net labor-year (after allowing for holidays and other non-productive absences). Dividing the 8225 labor-hours estimate by 1645 shows that five labor-years must be spent to complete the project design. Now assume that all the design is scheduled to be finished in the first six months of the program. This could be viewed (simplistically) as a project requirement of ten engineers for six months.

The manager starting this project might receive a rude awakening if he or she makes a top-down estimate for the project or refers to records of past projects. These might well show that projects of similar size and complexity took not ten engineers for six months, but the equivalent of ten engineers for a whole year. An apparent error of five labor-years exists somewhere. This is, in any language, a king-sized problem. Part of its cause could be the failure of estimators to allow for that part of engineering design which is sometimes called ‘after-issue’ work, which means making corrections, incorporating unfunded modifications, answering engineering queries from the workforce or the customer, writing reports and putting records to bed.

It goes without saying that cost estimates for a project are extremely important. Any serious error could prove disastrous for a fixed-price contractor—and for the customer too if it leads the contractor into financial difficulties. A competent person who is independent of the estimate compiler should, therefore, always check estimates as far as possible. Comparisons

with actual cost totals experienced on past projects (for all materials and labor, not just engineering design) are valuable in checking that the new cost estimate at least appears to be in the right league.

Because the project cost estimate will be used for many important commercial and management decisions, it is sensible to arrange for an authorizing signature from a responsible senior person who is satisfied that all reasonable care has been taken.

VERSION CONTROL OF PROJECT COST ESTIMATES

Version control is a subject of general importance to aviation project managers because of its relevance to traceability, safety and reliability in aircraft and aircraft systems. However, version control is important in the context of project specifications and cost estimates because of the need to ensure that the version of the project being estimated is the same version of the project that will actually be built. It is not unusual, especially for large capital projects, for protracted technical and feasibility discussions to take place between the contractor and the potential client before agreement and authorization of a final version of the project specification and its associated cost estimate. The client's ideas on project scope might change during these discussions, and some versions could envision different roles for the contractor. Proposed engineering solutions often change, particularly when the contractor's engineers are able to suggest alternative technical solutions that would bring mutual benefit to both the client and the contractor.

Project feasibility studies are another case where several versions of a project might be specified. Quite often a number of quite different project strategies are thoroughly investigated, each with its own project specification, cost estimate and financial appraisal report.

Each different version of a proposed project is certain to require its own, unique, cost estimate. It is therefore important to be able to relate every one of these different cost estimates to the relevant version of the project specification. Enormous risks could face a contractor if a fixed-price tender based on the wrong cost estimate were to be offered and accepted.

The solution is usually straightforward. Each different version of the project specification must be given a unique case number. For example, suppose that a project specification were to be developed and given the

serial number X1234. As different strategies and solutions are investigated, the relevant versions of the project specification would be numbered X1234 case A, X1234 case B, X1234 case C and so on. Each cost estimate can then carry the same serial and case number as its corresponding project specification.

Further refinement might be needed if any or all of these cost estimates should be reissued with corrections or small changes, in which case revision numbers would also have to be added. Thus, if an error resulted in the reissue of a cost estimate for project X1234 case B, the corresponding estimate would be labeled X1234 case B, revision 1 (the original would be issued at revision 0).

We mentioned that documentation can be a boring and uninteresting subject in Chapter 3, within the context of project definition. But version control is important for all significant project documents, not least the cost estimates.

6
Evaluating an Aviation Investment Project and Preparing a Business Case

Project evaluation (which often concentrates on project financial evaluation) is a complex subject to describe because there are so many different kinds of projects, even if we restrict our thoughts to the world of aviation. For all commercial projects, where a contractor carries out a project for a paying client or customer, the benefits will usually be perceived differently by the contractor and the customer. In general, the contractor will make a project profit or loss when the work is done and the customer takes over ownership. The project investor, however, will not usually expect to realize the financial benefits from the project until it has been implemented and is fully operational.

PROJECTS CARRIED OUT BY CONTRACTORS FOR EXTERNAL CUSTOMERS

Consider first the relatively straightforward case of a contractor that undertakes a project for an external customer. Here, as throughout this book, we are using the term contractor in its widest sense to mean any company or other organization that carries out any kind of project for a client or customer. The project might be, for example, an airport building, some highly specialized piece of aviation equipment or an IT project. Or it could be a 'soft' project such as a market research or other consultancy project. The contractor will usually have a relatively short-term involvement with the project and will expect to bank the final payment soon after the project is finished and handed over to the customer.

If the completed project was considered successful, the contractor's market reputation might benefit for a year or two to come. There might also be future benefits in the form of follow-up orders or a service contract for

maintenance or IT support. However, the contractor's principal benefits will usually be realized when the initial project is finished and the customer completes payment of the project price. Common risks are that the contractor's actual costs will exceed the estimated costs (which could spell disaster if the project was sold for a fixed price) or that the customer will default on paying the bills.

Projects are often governed by a contractor/customer contract that allows for interim payments during the design, procurement, building and commissioning stages. These stage payments are usually intended to assist the contractor in maintaining a healthy cash flow, but they will strengthen the tendency for the contractor to enjoy the project's financial benefits long before the investor begins to see any financial return.

Contractors for commercial projects will typically be invited by the customer to tender for the project in competition with several other potential contractors. The customer will usually set a deadline for the submission of tenders and that will restrict the time available for each contractor to consider the technical and commercial aspects of the project, decide the project strategy, estimate the time and costs, and then submit a priced proposal for doing the work.

Each potential contractor might make enquiries about the commercial viability of the customer, especially to find out whether or not that customer has a stable financial and organizational base. Naturally the contractor needs to be assured that the customer will not run out of cash and cease trading during the course of the contract. Independent organizations such as Dun and Bradstreet can make discreet enquiries to investigate the soundness and commercial probity of companies (http//:www.dnb.com).

Some customers simply never pay their bills on time as a matter of routine practice. This is another aspect of companies that Dun and Bradstreet can research on behalf of potential suppliers and contractors. One of us was once employed by a defense sub-contractor that was forced to refuse delivery of automatic test equipment to a military airfield until we were paid hundreds of thousands of dollars owed to us by the aircraft manufacturer for similar equipment delivered many months before.

However, all these matters fall within the normal realms of commerce. Contractors preparing bids for external projects usually have neither the need nor the time to become involved in the kind of predictive financial evaluation

processes for longer-term investment projects described in the remainder of this chapter.

INVESTMENT PROJECTS

This section describes projects in which companies invest money or other resources with a view to securing benefits at some time in the future. These might be R&D projects to develop a new product or service, which could be anything from designing a new landing gear to a complete aircraft for eventual production and profitable sales. Other examples are the purchase of a new IT system (perhaps for accounting systems, for flight bookings, for air traffic control or for one of many other reasons). An aircraft manufacturer might wish to invest in buying and installing a new automated machine. These kinds of projects can entail heavy 'up front' investment and it might be months or years before benefits start to be realized. A company might have to pay an external contractor's bills for the project long before any financial return is received for the investment.

People employed in the organization are often heavily involved in investment projects, and they will be expected to learn new processes and adapt to them. Organizational changes can result from investment projects in which people will be asked to move within the organization (and some might even be asked to leave). Clearly the full benefits of these investment projects will not be achieved if the staff cannot be encouraged to accept and adapt to the new situation. If an investment project of this kind fails, irreparable damage can be done to morale, and any subsequent project (even if it has merit) will probably be viewed with suspicion or even hostility at all levels of the company before it has a chance to get off the ground.

The airline that invests in buying a new fleet of aircraft will not expect to realize the full financial benefits until the planes have been put into service and attracted their full quota of paying passengers. The company that manufactured those aircraft will have spent years on R&D before it was able to put those planes into production and sell them. Twenty years is not an unusual time for an aircraft manufacturer to recover its original design and development costs for an aircraft.

All these kinds of investment projects demonstrate a clear need for careful financial forecasting and appraisal before the investment in money and other resources can be authorized.

Sometimes a company has to decide between two or more different strategies for undertaking an internal investment project. For example, an automated machining center might occasionally break down, but otherwise produces accurate work pieces. Should the company continue to bear the cost of these outages or instead invest in a new machine?

All these are the kinds of project investment cases that should initially be subjected financial evaluation before authorization. Senior management tasked with the responsibility for making high-level capital investment decisions deserve to be supported by the provision of a quantified business case (business plan). In addition to consideration of the company's people, the heart of a business plan should always be a financial evaluation of the cash flows and other benefits over the life of the project.

THE DIMENSION OF TIME IN PROJECT FINANCIAL EVALUATIONS

Much of this chapter is devoted to issues of forecast financial investments and the expected returns on those investments. All the following discussions are dependent in some way or another on time. We have to think not only about the amounts of money to be invested or gained, but also upon the time when each significant payment or receipt (cash flow) is expected to happen. Yet business plans, even those involving vast sums of money, are necessarily made at the beginning of project life cycles when no detailed project schedules are available.

So the important time element in business plans often has to be based on ballpark judgments. With not much detail available and sometimes only a fairly sketchy project specification, none of the more advanced planning and scheduling methods described in Chapters 12 through 16 can be used at this early stage in the project life cycle. So it is often necessary to fall back upon the relatively primitive method of guessing (perhaps we should say inspired guessing) when the main project events will take place. We must, of course, take as much care as possible in this process, and experience with past projects can help us to forecast what the main events will be and when they will most likely happen.

Our primitive early plans can either be presented as a list of target dates or (as we have done in every case in the early chapters of this book) as a

simple bar chart.

INTRODUCTION TO PROJECT FINANCIAL FEASIBILITY ANALYSIS

It is clear that no internally funded management project should be authorized without sanction from the most senior managers. They have to weigh the pros and cons and protect the company's interests and, ultimately of course, the shareholders' capital. This chapter is concerned with the long-term financial evaluation of proposed investment projects. Such evaluations typically lead to the preparation of business plans that will help senior managers in deciding whether or not to commit capital and authorize the project.

Managers frequently have to make decisions on whether or not to authorize investment in a project, or they might be asked to decide between two or more different project options. Depending on the type of project under consideration, the decision will depend on many factors, including answers to questions such as the following:

- Is the project feasible technically?
- Are we confident that the claims of the engineers, designers, consultants or architects are valid?
- What are the environmental implications?
- How will our existing staff be affected and can we count on their willing cooperation?
- Is the project likely to be finished on time?
- How much initial investment will be needed?
- What will be the ongoing or operating costs?
- Will new projects perform as predicted and will the benefits be as great as the experts claim?
- Is the proposed project strategy the best solution?
- What are the technical risks?
- What are the commercial risks?
- Is the return on our investment going to be adequate?
- For a management change project, have the intangible benefits been evaluated as well at the tangibles?

- How can we raise the investment money?

and so on.

It is sometimes necessary to commission one or more feasibility studies from independent experts to answer many of these questions. A feasibility study might examine more than one possible project strategy in depth. Some projects, such as those connected with winning metals, precious stones, oil or other minerals from the Earth's natural deposits can require feasibility projects that in themselves cost millions of dollars in consideration of many possible logistical and technical strategies and in exploration at the proposed project site.

There are two common approaches to financial appraisal. One is the simple payback or break even method. The other uses one of a range of techniques based on discounting the forecast cash flows. Whichever of these methods is chosen, the appraiser needs to have a good estimate of the amount and timing of each significant item of expenditure (the cash outflows) and of the revenue or savings expected (the cash inflows).

The main cash outflow elements of a project can include items such as the following:

- The initial acquisition cost of software, plant or equipment needed for the project. This might be a single purchase payment, a series of phased payments, or payments scheduled against a leasing or rental plan. The differences between these options are important not only for the timing of payments, but also for the tax implications.
- Interest payable on financing loans.
- If the project is for new machinery or plant, the costs of operating and maintenance.
- Commissioning, debugging and other implementation costs.
- Staff or operator training costs.
- All other expenses and fees payable as a result of the new project.

Against these items of expenditure must be balanced all the savings and revenues (the project benefits) that the new project is expected to generate. The following items are just a few of the many possibilities:

- Savings in operating and maintenance costs achieved by replacing old methods with the new project. For example, although a stainless steel tower bought to replace an old steel tower might be expensive initially it would have a longer life and would not need regular repainting.
- Revenue from the sale of products or services made possible by the new project.
- Proceeds from the sale of assets no longer required as a result of the new project.
- Proceeds from the eventual sale of the new project hardware, some time in the future, after the new project has reached the end of its economic life.

Fiscal measures can have a significant effect on the outcome. Many cash inflows will attract taxes, while some expenditure might be offset by allowances against taxation. Some capital investment projects might generate cash inflows in the form of government grants or special tax incentives and allowances. These circumstances vary considerably from place to place and from one country to another. They can complicate financial appraisal calculations considerably and are best handled by experts. The examples in this chapter illustrate general methods and have been kept relatively simple by excluding these fiscal elements.

There are several well-tried methods for appraising the financial outcome of projects, but these fall into two main classes, which are the simple payback or break even method and methods in which the cash flows are discounted. These methods and their terminology are best explained using a case example.

CASE EXAMPLE: AN AIRPORT VISITORS' CENTER BUILDING PROJECT

Every day a busy airport receives visitors from the local public who have no intention of flying but just want to have a nice day, watching the aircraft arrivals and departures. The airport's problem has been that these people cause a nuisance by cluttering the roads with their parked autos and obstructing vehicles carrying workers, passengers and freight to and from the airport. There are no toilet facilities accessible to spectators parked on or

near the perimeter roads and the airport authority is also understandably concerned about safety and security issues. ‘No parking signs’ have had little effect because the visitors simply park on the grass verges.

The airport authority welcomes positive and friendly interest in its operations from local people. Rather than discourage or alienate the sightseers, the airport owners have decided to cash in on this local interest by building a visitors’ center that will attract yet more sightseers but contain them in a safer place, where they can enjoy their time whilst paying for the privilege.

This visitors’ center will provide covered pay-on-exit parking at its lower levels. A restaurant, coffee lounge and souvenir gift shop above the parking levels will bring in additional revenue. ‘Comfort stations’ on every floor will put a welcome and much needed end to previous public hygiene problems. An observation lounge at the highest level will offer the visitors banked rows of seats facing big windows to give them a spectacular view of the airfield, including its two main runways. A high ratio of revenue to operating costs will be achieved by using automated services to keep staff numbers as low as possible.

The airport has an initial cost advantage in having land available which it already owns. But the airport’s resident architect is, to say the least, not cost conscious and, like many in that noble profession and our experience, enjoys leading edge creativity at the cost of expensive tastes in building design, construction materials, equipment and interior finishes. Thus the specification sent out by the airport’s architect inviting competing main contractors to tender for this project promised to result in an impressive landmark building. But high costs at the front of a project are often difficult to recoup in revenues from the subsequent ongoing day-to-day operation of the project.

Note that the term main contractor generally (and here) implies a construction company that will engage all the sub-contractors and site labor, provide or hire the construction plant, make the detailed drawings from the architect’s specification, purchase all the equipment and materials, supervise the installation of bought-in equipment and generally manage the project for the airport. So the airport management will need to deal with only one external company.

The airport has appointed its resident architect as its primary point of contact with the main contractor. Thus this architect will oversee progress

and quality on behalf of the airport and examine all the main contractor's claims for payment.

Data Forecasts for the Airport Visitor Center Project

The main contractor's forecasts The airport has accepted a contractor's tender that promises to meet the high project specification in all respects. The contractor has provided the following data.

Proposed work program:

Sign main contract:	3 January 2011
Begin construction work on site:	16 May 2011
Building handover date:	28 September 2012
Clear all reported building snags:	22 December 2012

Forecast schedule of stage payment claims (to be supported by independently certified progress assessments):

Initial deposit on signing the contract:	$ 7 200 000
Total additional stage payments in 2011:	$24 800 000
Total stage payments in 2012:	$35 000 000
Final retention payment, 29 March 2013:	$ 5 000 000
Total project price	$72 000 000

Set against this price of $72 million, the main contractor's estimated total project costs are $62 million. Thus the contractor is expecting a target gross profit of $10 million (a modest gross profit of just under 14 per cent before tax). The contractor regards this cost estimate as confidential and will not expect to reveal its detailed internal budgets to the airport authorities.

The airport's project forecasts The airport, as the project owner, will view the estimated project data from a viewpoint that is quite different from that of the main contractor. The airport would summarize the project outlook as follows:

Project implementation program:

Sign the contract	3 January 2011
Occupy the building	28 September 2012
Finish internal works:	29 March 2013
Staff hired and trained	14 June 2013
Finish two-week trial	28 June 2013
Open to the public	1 July 2013

Capital costs:

To main contractor in 2011	$32 000 000
To main contractor in 2012	$35 000 000
To main contractor in 2013	$ 5 000 000
Internal set up costs in 2013	$ 9 000 000
Total expected capital costs	$81 000 000

Forecast operating costs:

In the opening year, 2013	$ 825 000
In each subsequent year	$ 1 650 000 (assumed constant for simplicity)

Forecast gross operating revenues:

In the opening year, 2013	$ 3 000 000
In each subsequent year	$ 6 290 000 (again assumed constant)

Commercial Aspects of the Airport Visitors' Center Project From the Main Contractor's Viewpoint

Consider the main contractor hired to build this visitors' center. The contract was won against competition, which restricted the profit margin and margin for error. So it is important for the contractor to complete this project within its budget.

The usual transaction arrangement is for the client (the airport) to pay the contractor an initial deposit when the contract is signed followed by pre-agreed stage payments that the contractor is allowed to claim when certain key project tasks (milestones) have been accomplished or when certified amounts of work have been done. When the building is eventually handed over to the airport for occupation, another payment will pass from the airport to the contractor. By this time the contractor should be in profit.

Construction contracts usually allow for a final settling-in period for the occupier, so that initial faults such as sticking doors, plumbing leaks, equipment malfunctions or faulty fixtures and fittings can be rectified free of charge by the contractor. This is often referred to as a snagging list procedure. Six months after being given the keys to the building this airport is contracted to make a final payment (known as a retention payment) that will bring the construction phase of the project to an end and peak out the contractor's profit. The airport would be legally entitled to delay payment of the final retention amount if any significant snags remain.

The proposed payments schedule set out above is also shown graphically against the relevant part of the project life cycle in Figure 6.1. This shows that the main contractor can expect to receive its full financial rewards soon after project completion and handover. The contractor's market reputation might also benefit from the publicity given to this high-profile project, provided of course that it was finished successfully.

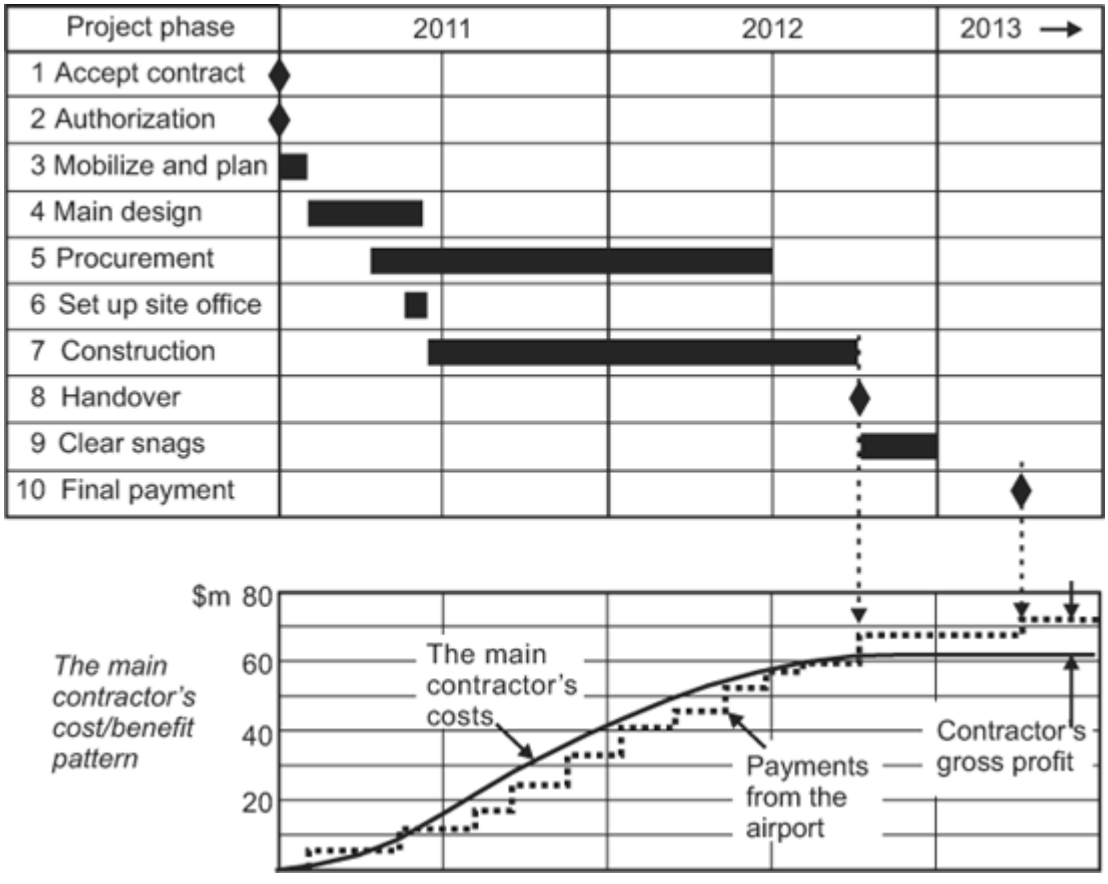


Figure 6.1 Contractor's cost/benefit pattern for an airport visitors' center project

Every project has its risks. Past and recent aviation history is littered with failed projects. Labor disputes, equipment malfunctions, design mistakes, project changes, poor performance by suppliers and sub-contractors, liquidity problems, tropical storms, site problems—any one of these could damage the project and convert the contractor's intended modest profit into a disastrous loss.

But when the contractor originally accepted this visitors' center project the issues were straightforward. Given the necessary resources and confidence in the commercial probity of the airport (that is, its willingness and ability to pay its bills) there was a clear indication that this would be a desirable construction contract. The issues that encouraged the main contractor were clear. This is a prestigious project with an outcome that can be predicted with some confidence and a fair (if modest) profit should result.

Similar arguments can usually be made for successful contractor-customer contracts in most construction or manufacturing projects (projects that we classified as Types 1 and 2 in Chapter 1).

Commercial Aspects of the Airport Visitors' Center Project from the Airport's Viewpoint

From the airport's point of view, this is a management project (an internally funded project of the kind that we classified as Type 3 in Chapter 1). The airport authority's association with this project began long before the contractor came on the scene and will continue for decades after the contractor has moved on to other work and other clients. The project will call for a significant initial financial investment, against which no financial return or other commercial benefit can be expected for over two years.

The forecast cost/benefit pattern for the airport visitors' center project as viewed by the airport is illustrated in Figure 6.2. This pattern is fairly typical of business change and other internally funded projects. However, we have simplified this case by assuming that all annual payments and revenues for future operations remain constant, year on year.

In many management change projects the impact on the organization's people will be significant and must be taken very seriously if the full benefits are to be realized. However that is not a main issue in this visitors' center case and the only real 'people issue' is recruiting suitable staff and training them at the appropriate time.

THE SIMPLE PAYBACK METHOD OF PROJECT FINANCIAL APPRAISAL

All of us are familiar with the simple payback or break even method of financial analysis. A common everyday example is seen when a salesperson visits or telephones us at home and tries to persuade us to invest in some home improvement project, such as improved heat insulation or double glazing. The salesperson might assure us that the proposed project will soon 'pay for itself' with the cost savings created. For example, if $5000 dollars spent on double glazing will cut $500 per annum from our heating and air conditioning bills, the project will 'pay for itself' in 10 years. Some of us would consider 10 years to be a very long time in such circumstances, but we might be persuaded to buy the project for environmental or other reasons.

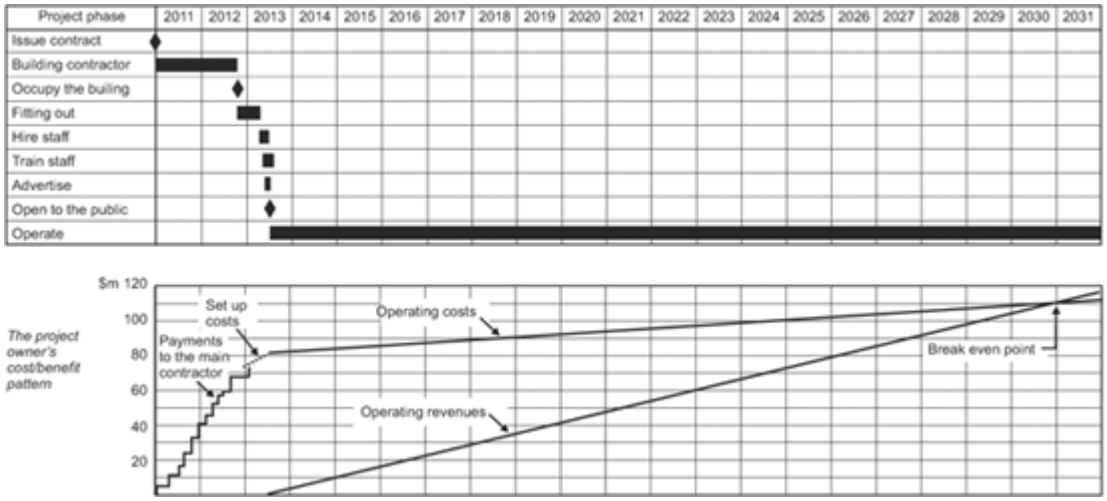


Figure 6.2 The project owner's cost/benefit pattern for an airport visitors' center project

For an aviation project example we can return to the airport visitors' center project. To help demonstrate payback and other methods, Figure 6.3 is a tabulation of the various financial values and predicted dates already given in Figures 6.1 and 6.2. However this tabulation is more convenient and accurate because it removes the errors of scaling that arise when reading figures off graphs.

All figures are $ '000s

Year	Item	Cash outflows	Cash inflows	Net cash flows	Cumulative cash flows
2011	Construction	32 000		– 32 000	– 32 000
2012	Construction	35 000		– 35 000	– 67 000
2013	Construction	5 000			
	Set-up cost	9 000			
	Operating cost	850			
	Operating revenue		3 000	–11 850	– 78 850
2014	Operating cost	1 650			
	Operating revenue		6 290	4 640	– 74 210
2015	Operating cost	1 650			
	Operating revenue		6 290	4 640	– 69 570
2016	Operating cost	1 650			
	Operating revenue		6 290	4 640	– 64 930
2017	Operating cost	1 650			
	Operating revenue		6 290	4 640	– 60 290
2018	Operating cost	1 650			
	Operating revenue		6 290	4 640	– 55 650
2019	Operating cost	1 650			
	Operating revenue		6 290	4 640	– 51 010
2020	Operating cost	1 650			
	Operating revenue		6 290	4 640	– 46 370
2021	Operating cost	1 650			
	Operating revenue		6 290	4 640	– 41 730
2022	Operating cost	1 650			
	Operating revenue		6 290	4 640	– 37090
2023	Operating cost	1 650			
	Operating revenue		6 290	4 640	– 32 450
2024	Operating cost	1 650			
	Operating revenue		6 290	4 640	– 27 810
2025	Operating cost	1 650			
	Operating revenue		6 290	4 640	– 23 170
2026	Operating cost	1 650			
	Operating revenue		6 290	4 640	– 18 530
2027	Operating cost	1 650			
	Operating revenue		6 290	4 640	– 13 890
2028	Operating cost	1 650			
	Operating revenue		6 290	4 640	– 9 250
2029	Operating cost	1 650			
	Operating revenue		6 290	4 640	– 4 610
2030	Operating cost	1 650			
	Operating revenue		6 290	4 640	30
2031	Operating cost	1 650			
	Operating revenue		6 290	4 640	4 670

Figure 6.3 Break even analysis for the airport visitors' center

The tabulation shows, for each year considered, the expected costs (the cash outflows), the anticipated revenues or savings resulting from the project (the cash inflows) and the difference between these quantities, which is the net cash flow for each year.

In the final column of Figure 6.3 the net cash flows have been added cumulatively year on year. At first, as expected, all the cash movements are outflows as the principal investment in the project takes place. But later these outflows are balanced and eventually outweighed by revenues earned by the project. At the end of the year 2030 the cumulative outflows are finally surpassed by the revenues, to become a net positive inflow. The project's break even point has been reached and the original investment has been recouped. Note that, as we should expect, the graph in Figure 6.2 agrees with this result of a break even point at the end of Year 2030 (a project break even period of 20 years).

Further Consideration of the Break Even Forecast

The results of simple break even analysis, especially when the periods concerned span many years, can often be too simplistic and misleading. Except for very obvious cases where a project can pay for itself in a matter of months or, at the most, a couple of years, other factors must be taken into account.

Thanks principally to the high parking charges, the investment of $81 million in the airport visitors' center project is expected to result in annual revenue of $4.64 million after operating expenses but before tax. That apparently represents a pre-tax return on investment of just over 5.7 per cent. That result might compare well with other possible forms of investment, such as simply placing the capital in a deposit account with a bank. But there are important drawbacks to this argument.

If the airport had to borrow some or all of the $81 million initial capital, then it would have to make repayments until the loan had been repaid. If that had been the case, we should have shown the loan receipt as a cash inflow at the beginning of the project, but subsequent years would have included the loan repayments (including interest) as cash outflows. Those cash flows would have to be included in the schedules (Figures 6.2 and 6.3).

For simplicity, we have assumed that the airport can pay for the airport visitors' center from its reserves. That still leaves the problem of committing

and investing $81 million over the early project years for no interest or other return on the capital at all. That is clearly less advantageous than leaving the money in a bank deposit, where it would earn compound interest day by day from the date of its original investment. Further, although interest rates can change, the risk of depositing money in a reputable bank is less than the risk of investing it in a project, because in the project case none of the forecast benefits can be guaranteed and the estimated capital requirement of $81 million might be exceeded. There are plenty of examples of public and aviation projects that have cost more than twice their original budgets.

There is another difficulty with the simple break even method when the payback period would extend beyond one or two years (as in this case). A given sum of money earned or spent in the future has less effective value than the same sum of money earned or spent today. For example, suppose that you want to buy a luxury item for $10 000 and you have the option of deferring payment at no extra cost for three months. Clearly you would accept the credit option because $10 000 payable in three months' time is better for your personal cash flow and if you have the money now but can leave it on deposit for three months you will earn some interest. So the $10 000 payable in three months time is effectively costing you less than $10 000 demanded today.

All future cash flows (in, out and net) for a project will have less effective value than the same amounts transacted today. These differences will grow as we look farther into the future. We are calculating the airport visitors' center project schedules over about 20 years, so we really must discount the future cash flows to compensate for the reduction of those money values with time.

DISCOUNTING THE CASH FLOWS

We begin this section by repeating the argument that any given sum of money earned or spent in the future has less real value than the same amount of money earned or spent today. If $100 received today could be invested for an annual net return of 10 per cent, that $100 should be worth $110 after one year. Put another way, if interest rates are running at 10 per cent, $110 received or spent in one year's time is equivalent to receiving or spending only $100 today. Today's $100 is called the discounted or *net present value* (NPV) of the future $110.

Likewise $100 received or spent in one year's time would be worth only $91 today. Over two years the NPV of that $100 would reduce to only $83. And so the NPV of any given sum will reduce depending on the time lapse and the rate of annually compounded interest. Figure 6.4 is a graphical representation to show how the NPV of $1 million would change over a range of 20 years for discounting rates of 2.5, 5, 7.5, 10 and 15 per cent.

Tables exist that give the NPV of $1 over a range of years for a number of different discounting rates. Accountants and actuaries found those tables useful in the past but now many computer programs can perform discounted cash flow calculations without the need to refer to tables. However, we have included a short table of discounting rates in Figure 6.5 which covers a range that is useful for most aviation projects.

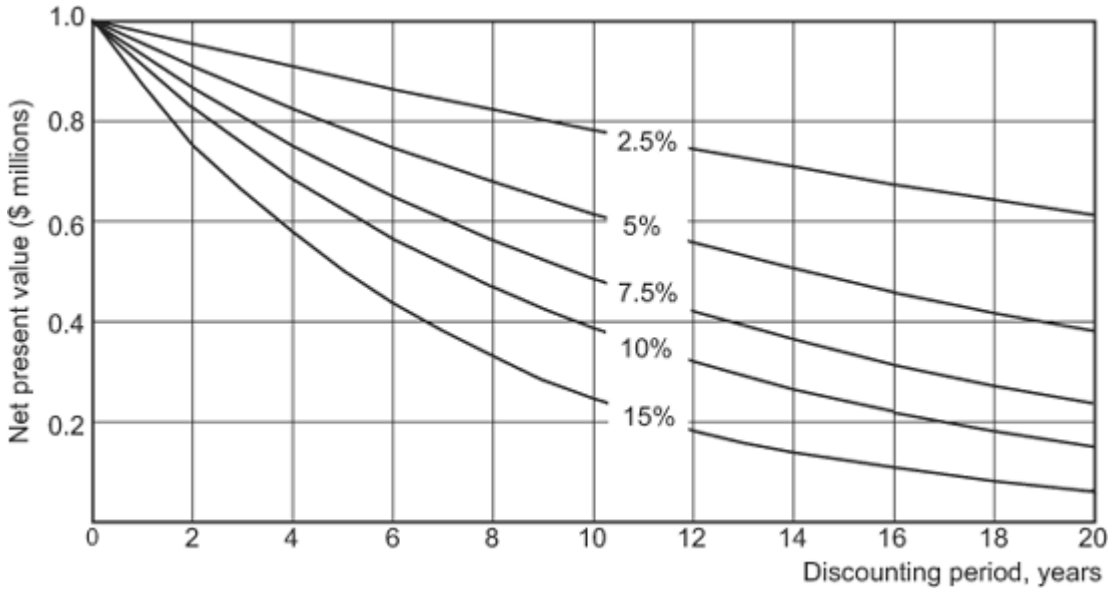


Figure 6.4 NPV of $1 million discounted over 20 years

	Net present value of $1														
Year	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%	11%	12%	13%	14%	15%
0	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1	0.990	0.980	0.971	0.962	0.952	0.943	0.935	0.926	0.917	0.909	0.901	0.983	0.885	0.877	0.870
2	0.980	0.961	0.943	0.925	0.907	0.890	0.873	0.857	0.842	0.826	0.812	0.797	0.783	0.770	0.756
3	0.971	0.942	0.915	0.889	0.864	0.840	0.816	0.794	0.772	0.751	0.731	0.712	0.693	0.675	0.658
4	0.961	0.924	0.889	0.855	0.823	0.792	0.763	0.735	0.708	0.683	0.659	0.636	0.613	0.592	0.572
5	0.951	0.906	0.863	0.822	0.784	0.747	0.713	0.681	0.650	0.621	0.594	0.567	0.543	0.519	0.497
6	0.942	0.888	0.838	0.790	0.746	0.705	0.666	0.630	0.596	0.565	0.535	0.507	0.480	0.456	0.432
7	0.933	0.871	0.813	0.760	0.711	0.665	0.623	0.584	0.547	0.513	0.482	0.452	0.425	0.400	0.376
8	0.923	0.854	0.789	0.731	0.677	0.627	0.582	0.540	0.502	0.467	0.434	0.404	0.376	0.351	0.327
9	0.914	0.837	0.766	0.703	0.645	0.592	0.544	0.500	0.460	0.424	0.391	0.361	0.333	0.308	0.284
10	0.905	0.820	0.744	0.676	0.614	0.558	0.508	0.463	0.422	0.386	0.352	0.322	0.295	0.270	0.247
11	0.896	0.804	0.722	0.650	0.585	0.527	0.475	0.429	0.388	0.351	0.317	0.288	0.261	0.237	0.215
12	0.887	0.789	0.701	0.625	0.557	0.497	0.444	0.397	0.356	0.319	0.286	0.257	0.231	0.208	0.187
13	0.879	0.773	0.681	0.601	0.530	0.469	0.415	0.368	0.326	0.290	0.258	0.229	0.204	0.182	0.163
14	0.870	0.758	0.661	0.578	0.505	0.442	0.388	0.341	0.299	0.263	0.232	0.205	0.181	0.160	0.141
15	0.861	0.743	0.642	0.555	0.481	0.417	0.362	0.315	0.275	0.239	0.209	0.183	0.160	0.140	0.123
16	0.853	0.728	0.623	0.534	0.458	0.394	0.339	0.292	0.252	0.218	0.188	0.163	0.141	0.123	0.107
17	0.844	0.714	0.605	0.513	0.436	0.371	0.317	0.270	0.231	0.198	0.170	0.146	0.125	0.108	0.093
18	0.836	0.700	0.587	0.494	0.412	0.350	0.296	0.250	0.212	0.180	0.153	0.130	0.111	0.095	0.081
19	0.828	0.686	0.570	0.475	0.396	0.331	0.277	0.232	0.195	0.164	0.138	0.116	0.098	0.083	0.070
20	0.820	0.673	0.554	0.456	0.377	0.312	0.258	0.215	0.178	0.149	0.124	0.104	0.087	0.073	0.061
21	0.811	0.660	0.538	0.439	0.342	0.294	0.242	0.200	0.165	0.135	0.112	0.093	0.077	0.064	0.053
22	0.803	0.647	0.522	0.422	0.326	0.278	0.226	0.184	0.151	0.123	0.101	0.083	0.068	0.056	0.046
23	0.795	0.643	0.507	0.406	0.310	0.262	0.211	0.170	0.139	0.112	0.091	0.074	0.060	0.049	0.040
24	0.788	0.622	0.492	0.390	0.295	0.247	0.197	0.158	0.127	0.102	0.082	0.066	0.053	0.043	0.035
25	0.800	0.610	0.478	0.375	0.281	0.233	0.184	0.146	0.117	0.093	0.074	0.059	0.047	0.038	0.030
26	0.772	0.600	0.464	0.361	0.268	0.220	0.172	0.153	0.107	0.084	0.066	0.053	0.042	0.033	0.026
27	0.764	0.586	0.450	0.347	0.255	0.207	0.161	0.125	0.098	0.076	0.060	0.047	0.037	0.029	0.023

Figure 6.5 Table of discount factors for calculating NPVS

Discounting the Airport Visitors' Center Cash Flows to Find the NPV

Suppose that the airport which is about to embark on the visitors' center project usually expects to make a return on its investments of not less than five per cent per annum before tax.

In Figure 6.6 all the annual cash inflows and outflows have been tabulated and then, for each year, these have been used to find the net inflow or outflow (the net cash flow) for the year. The NPV of each year's net cash flow has been calculated, using the appropriate discounting factor for the year (taken from the table in Figure 6.5 in this case).

Although annual cost inflation can also have a significant effect, it is usually ignored for the purposes of appraisal calculations (partly because the

amounts arising from inflation usually occur on both sides of the inflow/outflow equation and therefore tend to cancel out). Tax, however, cannot be ignored in the real world, both where payments are due and where advantages such as allowances or government grants can be added to the cash inflows. We have left these fiscal considerations out for simplicity.

In the final, right-hand column of Figure 6.6 the cumulative discounted cash flow for the project is shown for each year. Now when year 20 is reached the project does not break even, but there is still a negative NPV of $28 251. It will be many more years before the NPV reduces to zero and finally becomes positive. So the true rate of return on this project over 20 years is well below 5 per cent over 20 years (it is close to zero).

All figures are $ '000s

Year	Item	Cash outflows	Cash inflows	Net cash flows	Discount factor 5%	Discounted cash flows
2011	Construction	32 000		– 32 000	1.000	– 32 000
2012	Construction	35 000		– 35 000	0.952	– 32 961
2013	Construction Set-up cost Operating cost Revenue	5 000 9 000 850	 3 000	 – 11 850	 0.907	 – 10 748
2014	Operating cost Revenue	1 650	 6 290	 4 640	 0.864	 4 009
2015	Operating cost Revenue	1 650	 6 290	 4 640	 0.823	 3 819
2016	Operating cost Revenue	1 650	 6 290	 4 640	 0.784	 3 638
2017	Operating cost Revenue	1 650	 6 290	 4 640	 0.746	 3 461
2018	Operating cost Revenue	1 650	 6 290	 4 640	 0.711	 3 300
2019	Operating cost Revenue	1 650	 6 290	 4 640	 0.677	 3 141
2020	Operating cost Revenue	1 650	 6 290	 4 640	 0.645	 2 993
2021	Operating cost Revenue	1 650	 6 290	 4 640	 0.614	 2 849
2022	Operating cost Revenue	1 650	 6 290	 4 640	 0.585	 2 714
2023	Operating cost Revenue	1 650	 6 290	 4 640	 0.557	 2 585
2024	Operating cost Revenue	1 650	 6 290	 4 640	 0.530	 2 459
2025	Operating cost Revenue	1 650	 6 290	 4 640	 0.505	 2 343
2026	Operating cost Revenue	1 650	 6 290	 4 640	 0.481	 2 232
2027	Operating cost Revenue	1 650	 6 290	 4 640	 0.458	 2 125
2028	Operating cost Revenue	1 650	 6 290	 4 640	 0.436	 2 023
2029	Operating cost Revenue	1 650	 6 290	 4 640	 0.416	 1 930
2030	Operating cost Revenue	1 650	 6 290	 4 640	 0.396	 1 837
Net present value of project discounted at 5% over 20 years						– 28 251

Figure 6.6 Calculation of NPV for the airport visitors' center

Using Discounted Cash Flows to Find the Internal Rate of Return (IRR) on Investment

If a calculation such as that shown for the airport visitors' center in Figure 6.6 is repeated several times for a range of different discounting rates, a rate should be found that gives a NPV somewhere near zero. Then, either by drawing graphs or by reiterating the calculation with finer per cent gradings a

discounting rate should eventually be found that yields a project NPV that is exactly zero. The discounting rate that yields a net present project value of zero is equivalent to the internal rate of return (IRR) that the project is expected to earn over the period examined.

Try this on the airport visitors' center project over 20 years and you will find that the rate of return is itself zero.

HOW MUCH CONFIDENCE CAN WE PLACE IN THE DATA?

The results of project financial appraisal can be the prime factor in deciding whether or not to commit vast sums of money in launching a new project. Senior managers who are presented with a business case will, if they are good at their jobs, ask searching questions. In particular, they should be asking how much confidence can be placed in the data used in the appraisal. Most estimators and analysts tend to be too optimistic in their predictions. A financial appraisal that predicts a good, very positive NPV at the end of several pages of tables and arguments can be very persuasive. However, many of the estimates of costs and time used to build up the business case are only estimates, made as judgments by fallible human beings. They are not facts set in tablets of stone. Quite often, the estimators get it wrong and the project fails to produce all the expected benefits.

We need to make some sense out of such uncertainty. Two commonly used methods are sensitivity analysis and Monte Carlo analysis. Both of these methods deal with the possibility that the data are flawed in some way. Chapter 17 deals more comprehensively with uncertainty and other forms of risk.

Sensitivity Analysis

Sensitivity analysis is one way to gain more confidence in the reliability of a project financial appraisal. The process consists of reiterating the discounted cash flow calculations with a slightly changed value for one or more of the parameters to test the effect (sensitivity) on the predicted NPV. So, for example, we might try the calculations with the annual revenues increased by 5 per cent, and then again with them reduced by 5 per cent.

In the appraisal calculations for the airport visitors' center we might, for instance, try the effects of reducing the capital costs by downgrading the specification. Or we could test the results of the capital budget being overspent by, say, 5 per cent. Then, again, we could test for variations in the ongoing project operating costs or in the revenues generated.

Another factor that should be tested is the effects of changed project completion date. What would be the effect of the opening date being advanced or delayed by three months? By six months?

After each change, the project's NPV must be recalculated to assess the impact of the changed parameter. The sensitivity of NPV to these changes will help to indicate the reliability of the financial appraisal.

Monte Carlo Analysis

Monte Carlo analysis is a statistical method, associated with some very impressive (but to most of us not very helpful) mathematics. Fortunately, the process is made simple for project managers and financial analysts by the number of off-the-shelf software applications now available. Developments in project management software were at first focused on attempts to predict the probability of finishing a project on time. This was a development of PERT, Program Evaluation and Review Technique, a method that is explained in Chapter 14. PERT caters for uncertainty in estimating the duration of a task, and it allows the planner to specify a most pessimistic, most optimistic and most likely value for each task. When the plan is run on a computer using Monte Carlo analysis, many reiterations of the plan can be calculated with all the task durations chosen at random from one of their three estimates.

These same principles can be applied to cost estimates and forecast benefits. The estimator or some independent authority must first review each cost estimate and from it produce two further estimates. Thus, for every original cost item estimated, three estimates must be tabled. These are as follows:

1. The original estimate, which should be the most likely cost expected for the item.
2. A higher estimate, set at the highest possible or most pessimistic cost estimate for the item.

3. A lower value, which is the lowest possible, or most optimistic cost estimate for the item.

Thus every item on the original task list will now have three estimates attached to it, the most likely, the most pessimistic and the most optimistic. Monte Carlo analysis makes use of these different estimates by substituting them at random in many reiterations of the total project cost estimate. At one extreme the computer calculation might contain all the improbably low estimates. At the other extreme all the highest, most pessimistic estimates would be included. Between these least likely calculations, the computer can be made to carry out a great number of project cost calculations in which any of the three possible estimates for each cost item is used at random.

Figure 6.7 shows the kind of result that Monte Carlo analysis can produce after many hundreds or even thousands of repeat calculations. The height of each vertical bar in the histogram indicates the frequency, which is the statistical term for the number of calculations that produce a particular estimated total project cost. The envelope containing these bars is seen to follow an approximately normal distribution curve about a mean figure of about $3.4 million.

In practice, the curve might be skewed towards a higher or lower probable total project cost but in this case the highest probability is that the project will cost $3.4 million. If the curve is slewed towards the right (that is, towards the higher cost end of the graph) that implies a higher risk of the project overrunning its budgets or even failing.

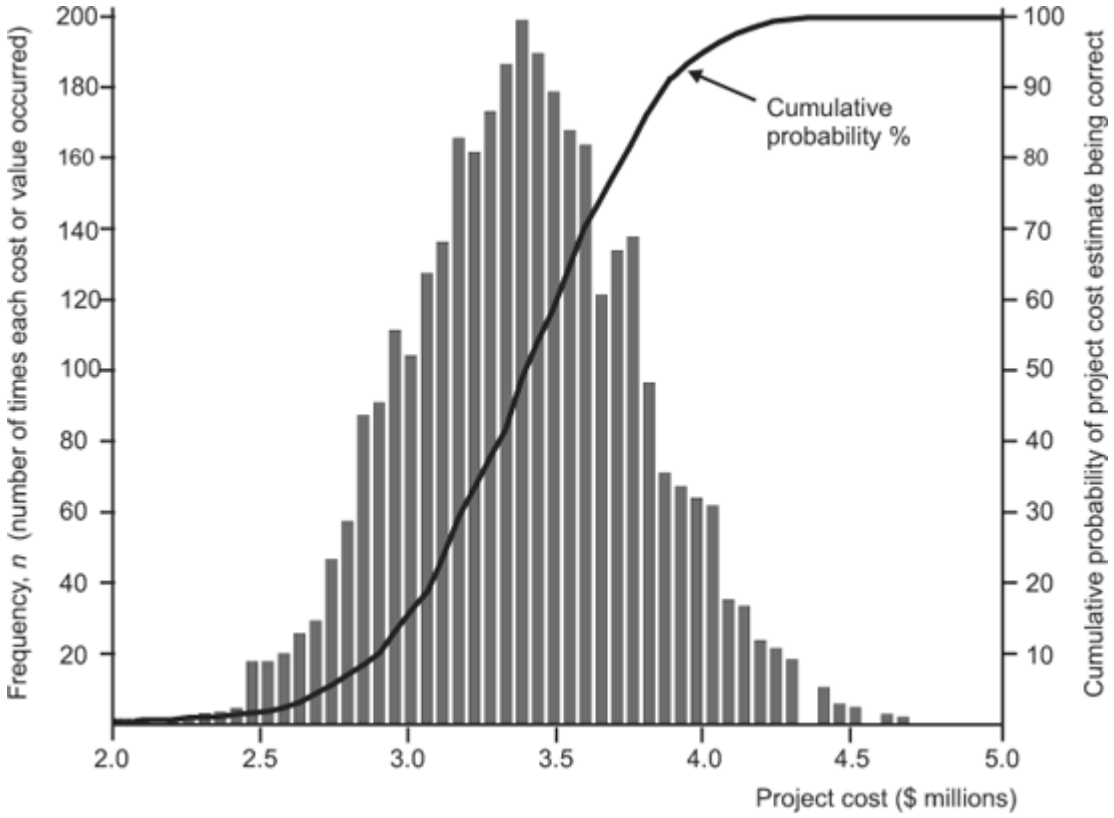


Figure 6.7 Typical report of a project's total cost probability from Monte Carlo analysis

Uncertainty in project benefit estimates Just as cost estimates can be subjected to Monte Carlo analysis, the same three-estimate approach can be used to assess the probability of achieving the desired project profits or longer-term benefits. Provided there are enough data, Monte Carlo analysis will produce another graph of the same form as that shown in Figure 6.7, but the distribution curve might have a quite different shape.

The Monte Carlo box diagram The results of the separate Monte Carlo cost and benefit analyses can be displayed together helpfully in a chart called a 'Monte Carlo Box'. Figure 6.8 shows the format used by the UK project management consultants Isochron Ltd. This chart demonstrates how project financial analysts might summarize and compare results from cost and benefit analyses in a business plan, using a format that is particularly helpful in communicating the forecasts clearly to the relevant senior managers.

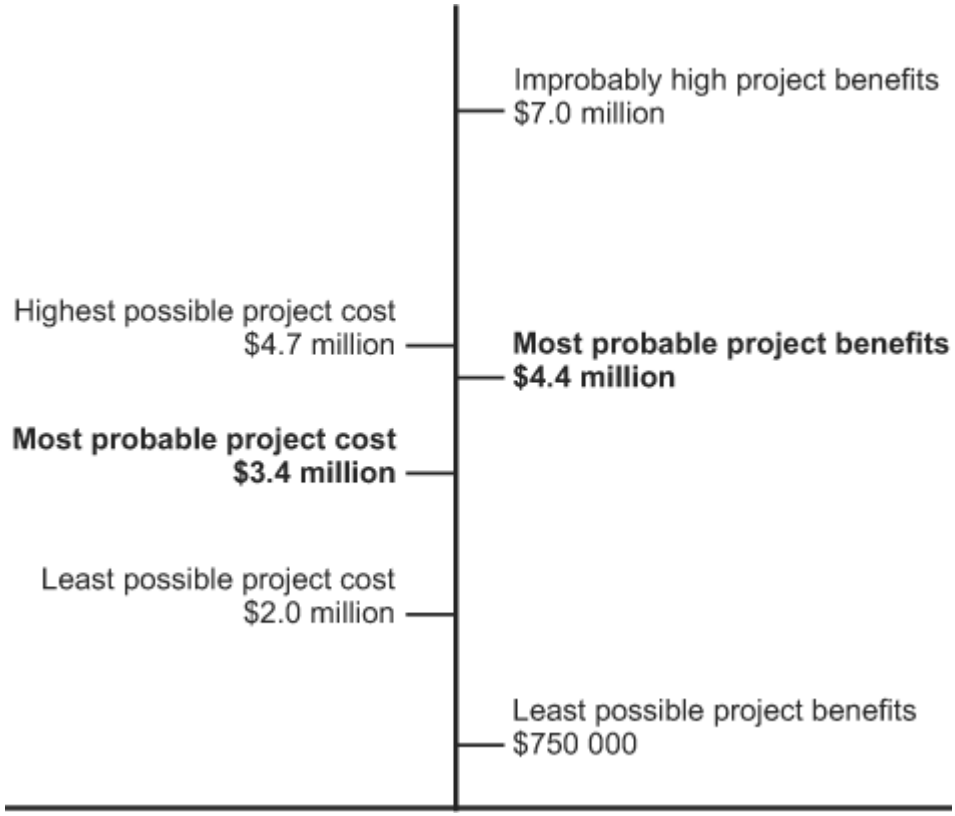


Figure 6.8 Chart comparing project cost and benefits after Monte Carlo analysis

Financial Appraisal: Not Always the Only Decision-making Criterion

Although financial predictions must always count heavily in business case presentations they are not always the deciding criteria on which project authorizations are based.

An airline operator that has been ordered to improve the maintenance and repair facilities for its entire fleet has no option but to embark on an internal investment project to improve its staff training, buy stocks of relevant spares and generally improve its procedures. A company that prepares in-flight meals on contract to one or more airlines would be forced to embark on an improvements project if the public health authorities issued an ultimatum threatening to close the business because of hygiene shortcomings. A hotel that has been served with a damning fire safety report must invest in a project to improve those premises and bring them up to a safe occupational standard to remove the risk to its guests and staff and to allow it to remain in business. One of us once had to authorize and manage a mandatory fire precautions project in our employer's offices that cost the equivalent of almost $1 million

in today's values for no realizable benefit other than allowing us to continue to use the premises.

Businesses are often faced with expenditure that they must undertake just to stay in business or for environmental or humanitarian reasons. For them, a business case presentation might still be necessary to allow choice between alternative strategies, but there could be no doubt that the company has no freedom to reject the proposal if it wishes to stay operational.

However, the following section deals with the more usual case where one or more individuals in a company have conceived the idea of an investment project that they feel will benefit the company. All they have to do is prepare and present a business case that will persuade their senior management to authorize the project and invest the time, money and other resources required.

PREPARING AND PRESENTING A BUSINESS CASE

The Written Case

We shall assume without question that every business case proposition shall be written in the form of a clearly written business plan. This should set out at least the following:

1. A summary section outlining the proposed project and the reasons why the company should invest in it.
2. A more detailed description of the project and the proposed strategy for undertaking it.
3. A bar chart or other simple form of chart showing the proposed timescale for the project, with the important milestone events.
4. A financial evaluation of the project, comparing estimated costs with the expected benefits. If the proposed implementation timescale exceeds one or two years, this financial evaluation should be based on discounted cash flows.
5. Suggestions for providing the resources required.
6. Any foreseen risks or difficulties that must borne in mind and provided for should the project be authorized.
7. Any effects on the existing workforce. For example, would additional specialist staff be needed, might some existing staff have

to be let go, or would staff have to be retrained or re-designated in their roles?

In some large business groups there might be several companies, each with its own managers who have original thoughts and ideas about how to spend the group's funds on management change projects. Indeed, the spirit of competition for recognition and promotion between managers in such groups has been known to engender such peer pressure that many feel encouraged to submit plans for new investment projects. Thus senior managers at group level are often faced with the difficult job of reviewing several proposals for new investment projects from numerous sources throughout the group.

In those circumstances the senior group managers should expect that all proposals for new investment projects are submitted to them in some prescribed format, so the salient facts of each proposal can more easily be found and compared with those of other proposals.

Presenting the Business Case

Some advocates for investment projects are fortunate enough to be invited to attend a meeting with the corporate senior managers and present their business case in person. Needless to say, preparation for this event is always most important. Presentation of a business case in person does not remove the need for a written business plan in the form described in the previous section.

PowerPoint slides can be a useful aid in highlighting the best features and data of a business case, but the presentation should be kept short, long lists of bullet points must be avoided at all costs, and each slide should have large type, conform to a chosen color scheme, and be animated wherever this adds emphasis.

If the project proposition is for a project with a tangible output, such as a new building, piece of equipment or (especially) an aircraft, a small-scale model that the senior executives can see and touch will add interest and support the business case.

From personal experience we offer our sympathy to the enthusiastic progenitor of a business proposition who is invited to present the business case at a working lunch. Invariably the senior executives will be provided

with high-quality food and drink whilst the unfortunate presenter, who must keep talking, has to remain hungry and thirsty.

PROJECT FUNDING

Project Funding from the Project Owner's Viewpoint

Project funding may not be of direct concern to every project manager—unless shortage of funds puts the future of the project (and its manager) in question. However, here is a list of possible sources from which an organization may be able to find the capital needed for investment in a project:

- cash reserves (money held in the bank or in short-term investments, including profits not distributed as dividends to shareholders);
- sale of assets (for example, the owner of a stately home sells a valuable work of art to raise capital for a building restoration project, or a company realizes cash on its real estate in a sale and leaseback deal);
- mortgaging property;
- borrowing from a bank or other financial institution, either as an overdraft or as a fixed-term loan;
- borrowing through a lease purchase agreement;
- renting or leasing (in which case the project will be owned by the financing institution and not by the project user);
- issuing debentures or loan stock;
- raising share capital, either in a private or public company. The company may be specially set up for the project;
- collaborating with other companies to set up a consortium or a joint venture company in which skills, resources and risk are all shared;
- government sources at international, national or local level, through direct grants or fiscal incentives;
- for export projects it might be possible to borrow from a bank against security provided by a government's export credit guarantee scheme.

Project Funding from the Contractor's Viewpoint

Project funding considerations are not the sole concern of the purchaser. Contractors often need to take a serious interest in the financing of projects for several reasons:

- In some cases the contractor might offer to help or advise the customer to arrange finance. Financing proposals may even feature in the contractor's project tender.
- The contractor must be assured that the customer is financially viable, and has access to sufficient funds to meet all project costs. Will the customer be able to pay the bills?
- The contractor may need finance to invest in new plant or to expand other facilities in order to be able to carry out the project.
- If the project size is significant compared to the contractor's other work, cash flow will have to be considered. The contractor may have to fund costly work in progress until payment is eventually received from the customer. This difficulty can be made worse if invoices are disputed, delaying revenue receipts. Some customers pay late, not just through innocent tardiness but because of a deliberate policy to delay payment of every bill for as long as possible. The experienced contractor will attempt to minimize these effects by insisting on a contract that allows for progress payments, and by efficient invoicing and credit control methods.
- Money due from overseas customers can be particularly difficult to collect, with risk of serious delays or non-payment. It is easy for the inexperienced contractor to cause delay in payment through any failure (however trivial) to observe the complex documentation formalities imposed by some governments. The big banks are excellent sources of advice for those new to exporting.
- A contracting company will be able to reduce its borrowing requirement if it can improve its cash flow. The following are some of the methods that might be considered:

  1. Reducing inventory (stocks and work-in-progress);
  2. Using trade creditors to advantage, negotiating longest possible credit terms for the payment of suppliers' and sub-contractors' invoices;
  3. Keeping trade debtors to a minimum through prompt and accurate invoicing, asking for progress payments where appropriate, and

applying rigorous credit control.

There is more on cash flow management in Chapter 25.

7
Project Authorization

Project authorization is the formal process by which senior managers communicate their acceptance of a new project proposal throughout their organization. It is the signal to all line managers and other relevant staff that they have authority to begin project work and commit expenditure within their allocated budgets or cost estimates. This point in the project life cycle marks the important transition from investigative processes to the commitment of resources for action.

Previous chapters have indicated that there is a fundamental difference of approach during the preliminary life cycle phases depending on whether a proposed project would be carried out for a paying customer or would instead be an investment or management change project funded by the organization itself. However, once a project is authorized these differences vanish for most practical purposes. Any authorized project is a job that has to be planned, organized, supplied with equipment and materials and executed. This applies equally to internally and externally funded projects. Thus most active projects can be carried forward using a common project management methodology, the outstanding exception being projects for pure scientific research where the goals are not well defined.

This commonality across different types of projects applies equally to the project authorization process itself. There is usually no reason why one standard project authorization procedure should not be suitable in an organization for all its projects.

PURPOSES OF A PROJECT AUTHORIZATION PROCEDURE

The ideal form of project authorization procedure has to be suited to the value, complexity and importance of the projects normally handled by the organization. When considering the properties of an ideal procedure it is

perhaps best to begin by outlining what we expect an official project authorization to achieve. The principal purposes are listed below, not necessarily in order of importance:

1. To protect the best interests of the company by ensuring that capital or other significant expenditure can only be committed on work that has the approval of senior management, either through approval of a business case for an investment project or as a result of a contract with a customer.
2. To announce to all relevant people in the organization that senior management approval has been given for a new project to start. In other words, to act as a wake-up call to initiate work on the project.
3. To communicate details of the project nature and scope. Project authorizations often refer to supporting documents such as specifications and concept drawings.
4. Where the project is for an external customer, to list the customer's name and address, the contract or order number, and the billing arrangements (with prices in some cases).
5. To announce the project's name and number as it will appear in all accounts and reports, other codes, and in the management information system database.
6. To announce key project milestone dates or targets.
7. To list summary budget information, by department or other suitable breakdown.
8. To list any restrictions, for example in a provisional authorization that releases only part of the budget or specifies only a limited amount of work.
9. To announce the name of the project manager and confirm his or her authority to manage the project.

PROJECT AUTHORIZATION AS A CHAIN REACTION

Once a project of any significant size has been fully authorized by its owner it is common for many other companies to become involved as contractors, sub-contractors, suppliers, consultants and so on. Thus project authorization by the project owner or in a main contractor's organization usually triggers a chain reaction. This begins with the project owner making the initial decision

to invest money in the project, usually against the expectation of valuable benefits to be realized much later in the project life history. When contractors or other external companies are engaged by the owner to work on the project, they too will apply project authorization procedures within their own organizations before they allow their staff to begin work or place their own external purchase orders and sub-contracts. However, the authorization criteria for these contractors and suppliers will depend not on their assessments of longer-term post-project benefits, but on the more immediate revenues and profits expected at or before project completion.

MANY VARIATIONS ON THE AUTHORIZATION THEME

Project authorization procedures vary from one industry to another and between different companies in the same industry. Astonishingly, there are companies that have no formal procedure at all. The subject is often ignored in project management textbooks (one exception is Rosenau and Githens, 2005), At the simplest practical extreme in aviation is a light general aviation aircraft maintenance facility where pre-printed works order forms allow a new job file to be opened immediately each customer presents an aircraft for repair or for scheduled maintenance as required by the regulatory authority.

Minor Projects that Do Not Require a Formal Project Authorization Process

Clearly, every company will need to authorize internal projects of a minor nature from time to time, when the full force of a formal authorization procedure would be inappropriate. Examples include the overhaul and repair of a machine, curing a leaky roof, carrying out repairs to a building, redecorating offices, buying new furniture and so on. Although such work can be costly a prudent board of directors will usually allow discretionary power to named more junior managers that allow them to authorize some routine internal projects on their own authority, without need for further reference to the board. For example, a buildings maintenance manager at an airport should not be expected to go through a formal project authorization procedure when a building needs redecorating or some internal rearrangement of partitions. Such minor projects and small works can be

treated as operational expenses within the annual budget allocated to the manager.

However, whenever any manager is given independent authority to initiate expenditure, fraud prevention demands that a different manager should approve all resulting invoices for payment of significant sums to external suppliers and contractors. To explain the reason for such precautions, consider the extreme (but not unknown) case of a manager who could authorize a project for work on his or her private residence, fraudulently using company funds. Unless an independent manager sees the incoming invoices for approval, the fraud might go unnoticed.

Authorization by internal memorandum Small in-house projects are often authorized by an internal memorandum issued by a senior manager to the department or project manager responsible. For example, an airline may decide to carry out an internal removals program which means relocating staff, during which some partition changes will be needed with consequent repairs to carpets and wall coverings. This might also mean finding temporary occupation for the staff affected for two or three weeks. That work must certainly be managed as a project, but it hardly needs an elaborate authorization procedure. A memorandum from the managing director to the facilities manager specifying the requirements and the budget is all that is needed. A project authorization is not required because all the costs can be charged to an existing overhead account budget and it is not necessary to add a new project to the management information system database.

An internal memorandum that authorizes a small project constitutes a contract between the project owner (represented by the board of directors or senior management in this case) and the ‘contractor’ (which, for an internal project, is the departmental manager to whom the memorandum is issued).

Charter and Contract

The extreme opposite to a simple authorization procedure is seen in companies that, after the initial project appraisal, prepare a project charter document that defines the project in admirable detail but takes months to write and approve.

When the project charter has been approved, the company then compounds the complexity by spending yet more time in creating a project contract,

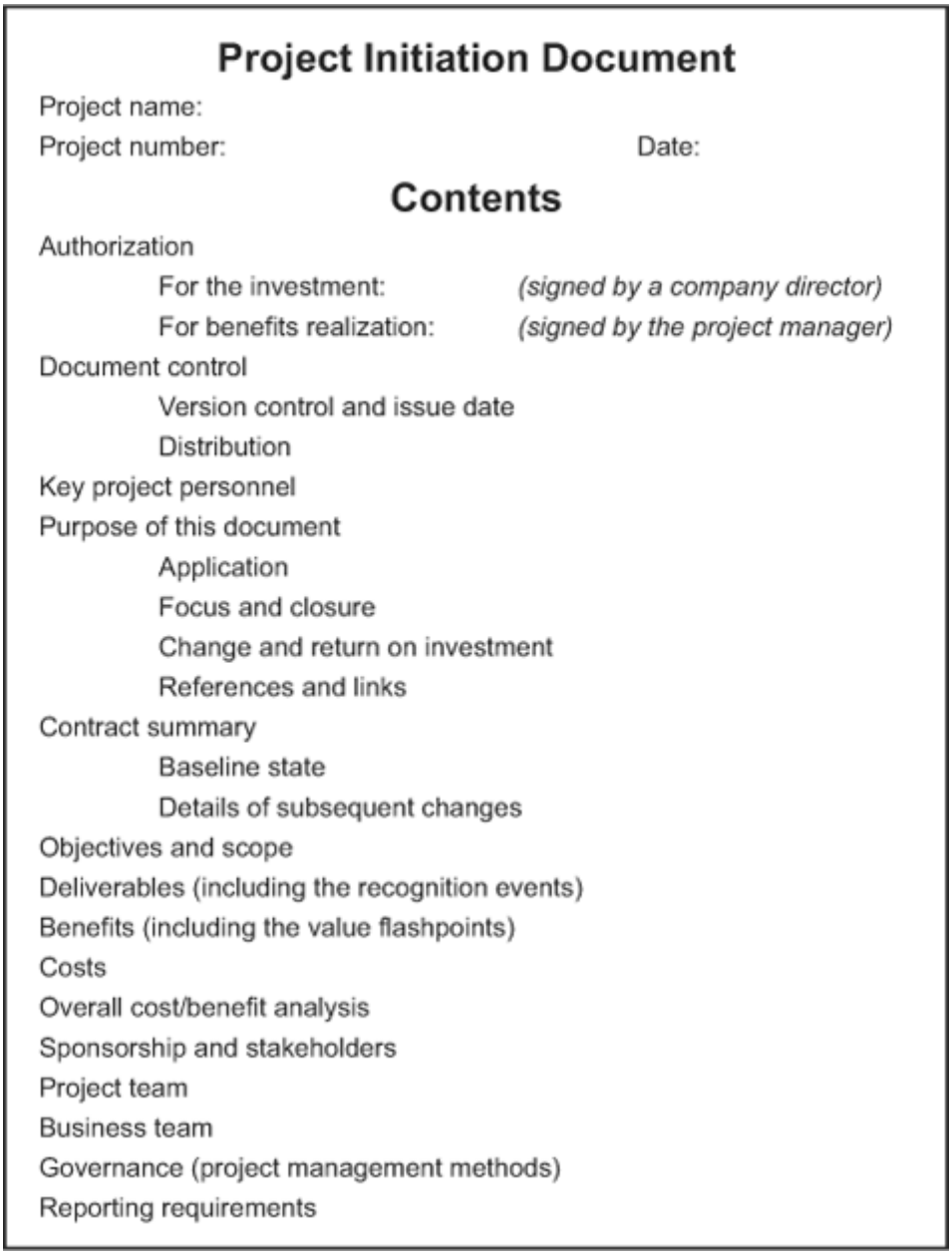
which is a contract only in the sense that the company creates a virtual contract with one of its own employees who is to be the appointed project manager.

This complicated procedure will add time and cost to the project, but no value. We know of one company where this process can take up to six months, with consequent delay to starting the project.

For some internally funded projects where there is no project specification from an external customer and no contract setting out the commercial terms, the charter and contract method is probably the best way to document the project requirements. This is especially true for projects that will need considerable capital investment or will have a profound effect on staff. However, no authorization procedure must be allowed to take up too much time and delay the project. A project which is not allowed to start on time cannot be expected to finish on time.

Authorization Using a Project Initiation Document

Although still fully comprehensive, a project initiation document (PID) of a form similar to that shown in Figure 7.1 is a concise and more practical alternative to the charter and contract arrangement. The PID can fulfill both the role of the charter and of the contract. This example is included with the permission of Isochron Ltd.



Project Initiation Document

Project name:

Project number: Date:

Contents

Authorization
- For the investment: *(signed by a company director)*
- For benefits realization: *(signed by the project manager)*

Document control
- Version control and issue date
- Distribution

Key project personnel

Purpose of this document
- Application
- Focus and closure
- Change and return on investment
- References and links

Contract summary
- Baseline state
- Details of subsequent changes

Objectives and scope

Deliverables (including the recognition events)

Benefits (including the value flashpoints)

Costs

Overall cost/benefit analysis

Sponsorship and stakeholders

Project team

Business team

Governance (project management methods)

Reporting requirements

Figure 7.1 Typical contents list for a project initiation document (PID)
By kind permission of Isochron Ltd.

Works Orders and Similar Procedures

A very common form of authorization procedure is the one or two page document that is issued to all company departments to summarize the project requirements and announce that the project is open and authorized. This document is often called a project authorization or a works order.

Figure 7.2 shows a works order form of a type that has been used for many years in companies undertaking manufacturing projects. The information given on budgets and schedules is necessarily brief, and is provided on the form only to allow outline planning and to place overall limits on the amount of expenditure authorized. Detailed budgets and work-to lists usually take some time to prepare and may be delayed by several weeks after the project is authorized.

Works order | Project number

Customer | Delivery address (if different)

Project title

Drawings, specifications and other documents defining this project | Number | Rev

Budget summary	*Hours*
Engineering design	
Design after issue	
Works	
Assembly	
Final testing	
Installation	
Commissioning	
Materials, services and expenses	$

Schedule summary Project start and finish dates are firm. Others subject to detailed planning.

	Start	*finish*
Design and drawing		
Purchasing		
Manufacturing		
Assembly		
Final test		
Install and commission		
Overall project dates		

Commercial summary

Sales engineer:

Sales reference:

Customer's order No.

Contract type and total price

Notes/limitations

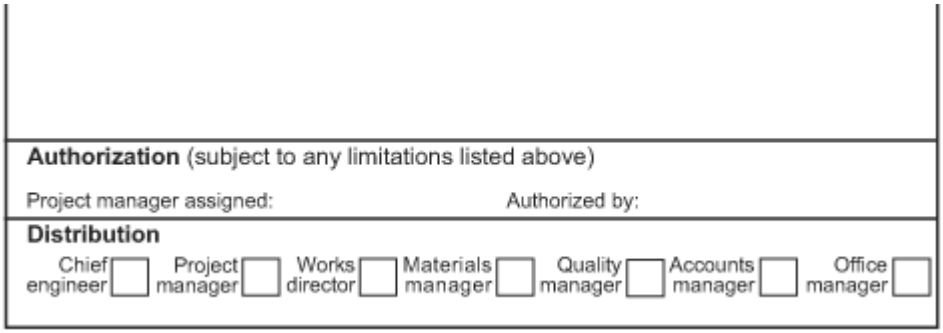
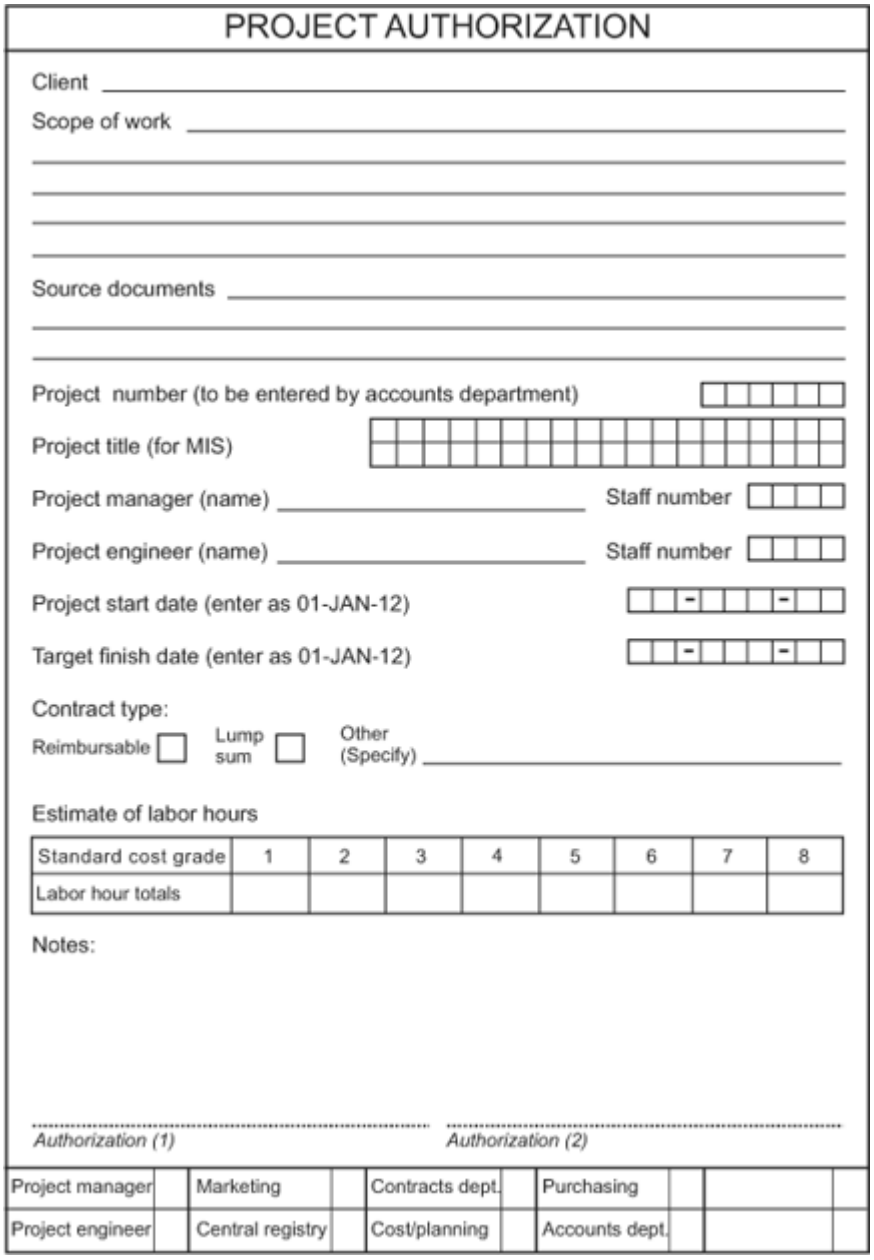


Figure 7.2 Works order example for a manufacturing or R&D engineering project

Figure 7.3 shows a project authorization form used by a mining engineering company to initiate and authorize projects ranging from small feasibility studies and minor plant extensions to very large capital projects. This form would be applicable to many types of aviation projects, for example in construction work at airports. This form summarizes the essential project data as it would be entered into a new project file in the company's management information system. This particular example was issued with a tabulated summary of departmental budgets on its reverse face.



PROJECT AUTHORIZATION

Client _____

Scope of work _____

_____

_____

_____

_____

Source documents _____

_____

_____

Project number (to be entered by accounts department) ☐☐☐☐☐☐

Project title (for MIS) ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐

Project manager (name) _____ Staff number ☐☐☐☐

Project engineer (name) _____ Staff number ☐☐☐☐

Project start date (enter as 01-JAN-12) ☐☐-☐☐☐-☐☐

Target finish date (enter as 01-JAN-12) ☐☐-☐☐☐-☐☐

Contract type:

Reimbursable ☐ Lump sum ☐ Other (Specify) _____

Estimate of labor hours

Standard cost grade	1	2	3	4	5	6	7	8
Labor hour totals								

Notes:

Authorization (1) *Authorization (2)*

Project manager		Marketing		Contracts dept.		Purchasing			
Project engineer		Central registry		Cost/planning		Accounts dept.			

Figure 7.3 An authorization form suitable for many applications such as an airport construction project

AUTHORIZATION CRITERIA FOR MULTIPLE PROJECTS

A company that regularly carries out any kind of commercial project for paying customers will usually welcome new orders and be grateful for every viable project that comes its way. However, resources usually have a finite

upper limit and limitations on those resources can sometimes cause a company to refuse new work and not authorize a project that in leaner times would be very welcome.

The authorization decision for a new internally funded project will certainly be complicated if other management change or IT projects are already in progress in the organization, or if the application for the project is one of several such applications. Apart from the question of resources and available funds, some management change projects can interfere with each other. This takes us into the territory of *portfolio management.* Very often, companies have to make a choice between different projects, any one of which might appear to be justifiable but for which resources cannot be made available. Managing a number of simultaneous projects within a company or group of companies is called *program management.*

Senior management must always be clear that the portfolio of authorized projects represents the best deployment of its available resources in terms of maximizing trading profits. Demands on the use of the same resources to support internally funded projects must be taken into account.

PROJECT REGISTRATION AND NUMBERING

Once a new project of any kind has entered an organization it has to be formally 'entered into the system' so that all the necessary accounting, planning, progressing and other administrative procedures can be put in place.

One of the first steps is to allocate an identification number to the new project which, depending on the procedures of the particular company, will be used henceforth as a basis for drawing numbers, cost codes and other important project documentation. Project numbers are usually derived serially from a register, which might be a loose-leaf book or a computer file. A typical project register page is shown in Figure 7.4. Project numbering, along with coding systems in general, is mentioned in Chapter 10.

The purpose of a project register is, of course, not only to allocate numbers. The register of current projects lists all authorized work within the organization against which time may legitimately be booked by staff on timesheets and against which the costs of project materials and expenses may be charged.

Whenever it is necessary to retrieve information about a project, current or long past, the project register is usually the best, often the only, starting place to begin the search. In most management information systems or archives, the project number is the essential element leading to the various document files and project data. But the project number might not be known or remembered. Very often historical searches start with only a vague recollection of the project description, or the name of the customer, or the approximate dates. Each project entry in the register should therefore record the following data:

- project title;
- start date and (eventually) closure date;
- project manager responsible;
- project number;
- the customer;
- the customer's order number or letter reference.

A well-kept register will enable any project to be identified long after it has been finished even when only one or two of the associated data items listed above are known. A secure copy of the register for all projects past and present should be kept in a secure but accessible archive.

DISTRIBUTION OF PROJECT AUTHORIZATION DOCUMENTS

Project authorizations are distributed to all company departments for general information, either as hard copy or via the company's management information system. However, the full supporting technical and commercial documents are handed over only to the project manager. It becomes the project manager's responsibility thereafter to ensure that all other managers in the organization are made aware of their particular project responsibilities in detail, and sufficiently in advance to enable them to make the necessary preparations.

AUTHORIZING WORK WITHOUT A CONTRACT OR CUSTOMER'S ORDER

The Golden Rule

One essential rule that all managers are taught is that no expense shall be committed on any project unless the customer's written authority to proceed (and promise to pay) has first been obtained. The risks for disobeying this rule are obvious. Once the customer knows that the contractor has already become committed to actual costs, the contractor's bargaining position in contract negotiations has been weakened. Worse still, if the customer decides not to go ahead with the project or give the work to another company, all the contractor's committed costs will be forfeit.

For these good reasons, an internal project authorization document will not normally be issued unless the customer's written authority to proceed has been obtained.

Breaking the Golden Rule

In spite of convention, there might be occasions when a very limited amount of work can be authorized before receipt of a firm order from the customer. Clearly this can pose financial risks. Indeed, to many work-hardened managers it will sound like heresy. But provided the risks can be quantified and contained within controlled limits it is often possible to gain several weeks' progress in the project calendar for the expenditure of only a tiny fraction of the total project cost. Of course, no orders for materials can be placed, but it might be possible to carry out activities from a preliminary project start-up checklist without committing more than one or two people over the limited period concerned.



Project register Date of last revision

Project number	Project title	Project manager	Customer	Date opened	Comments Special restrictions	Date closed

Figure 7.4 Example of a page from a company's central project register

Naturally, such advance work in the absence of a customer order will only be authorized where this strategy has advantages for the contractor. These advantages might include the avoidance of possible trouble later on, if the overall project timescale is seen to be particularly tight.

If the contractor foresees a trough in the organization's total workload, it could suit the contractor to carry out a little preliminary work, to enable full-scale work on the new project to start as soon as the order is received.

By these methods, progress on a new project might be pulled forward by a month or two. Conversely, doing absolutely nothing and waiting until the official order is received from the customer could mean that the main project workload will be delayed until it interferes with work for other projects.

Graphs of project expenditure plotted against time almost always approximate to a characteristic S shape and, indeed, are commonly called S-curves (see Figure 7.5). The rate of expenditure usually starts very slowly, increases greatly during the middle part of the project life cycle, and then falls off as the project nears completion. Any talk of authorizing advance expenditure must be limited to the first few weeks, when the rate of expenditure is very low and confined to preliminary engineering or administrative tasks. Steps must be taken to ensure that the expenditure rate remains low. Any decision to allow advance work is always risky, and this must be reflected in the conditions listed in the authorizing document. A

preliminary issue of the project authorization can be used but only with the following provisos:

- authorization must be limited to allow only one or two named individuals to do the work;
- the project accounting system should be programmed to reject time booked by people who are not on the authorized list;
- no materials or equipment must be ordered;
- there must be a total budget allocation for this work, regarded as the 'write-off' value of the risk;
- the work to be done should be defined and confined by a checklist or schedule;
- progress and costs must be monitored and reported to senior management so that work can be stopped immediately at any time.

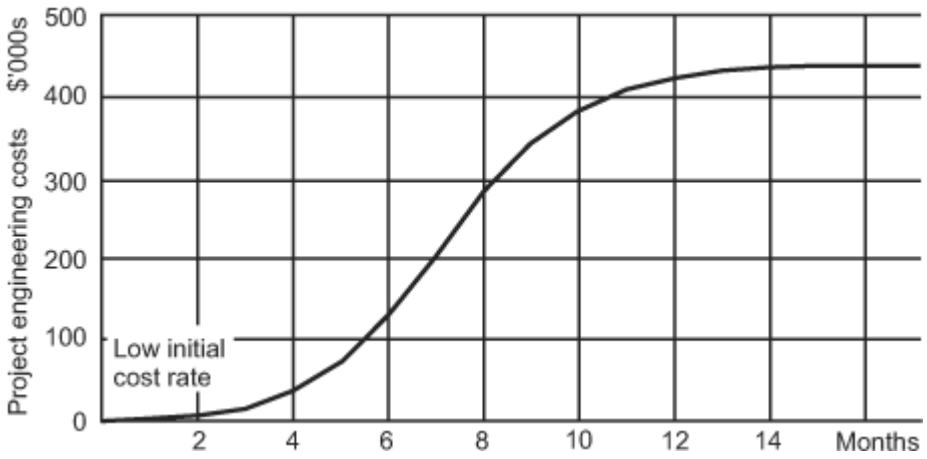


Figure 7.5 Typical cost/time relationship for an aviation engineering project

REFERENCES

Rosenau, M. D. jnr. and Githens, G. D., (2005), *Successful Project Management: A Step-by-Step Approach with Practical examples*, 4th ed., Wiley, New York.

One of few texts to give practical advice on project authorization.

8
Organizing the Project

An effective organization will ensure that the lines of authority are clear, and that everyone working on the project knows and willingly accepts what they have to do. This establishes the command and communication framework, which is essential for motivating all the people employed and for achieving a successful project outcome. A well-motivated group is a delight to manage. A badly informed group, with vague responsibilities and ambiguous levels of status and authority, is likely to be poorly motivated, slow to achieve results, costly to run and frustrating to manage.

ORGANIZATION CHARTS

It is not easy to discuss organizational structures in any depth of detail without the aid of organization charts (or *organigrams* as they are often unfortunately known). These charts are used and understood in most companies for general and project management purposes. For the benefit of students and others new to management we take time out here to explain the common conventions of these charts. Although no organigram can show every subtle aspect of a particular organization, there is no more convenient tool by which a company can communicate its organization structure to its own staff and to external companies. Thus you will find organigrams sprinkled liberally throughout this chapter.

Conventions Used in Organigrams

The chart in Figure 8.1 is for a company organized in what is generally known as a line and function structure. This is a very common arrangement in which people are arranged in departments according to their work functions, and the functions are managed through vertical lines of command. Although the organization in Figure 8.1 is very simple and not a project organization, it

does contain all the important organization chart elements and conventions and is a convenient base from which to begin describing organizations in this chapter. The generally accepted rules are as follows:

- Each chart box represents an organizational role, either for an individual job or for a set of people who comprise a functional group of department (for example, engineering design).
- The conventional preference is to write job or function titles in the boxes rather than people's names. Clearly job titles better describe the operating details of the organization. Although it is usually helpful to also include personal names, it is generally considered that the organization is a fairly stable pattern of roles, but the people assigned to those roles will be liable to change as they are promoted, demoted or 'given the opportunity to seek work elsewhere'.
- The authority and status of each role reduces from top to bottom of the chart in hierarchical fashion. So the most powerful role is placed at the apex of the chart.
- Solid lines indicate lines of command, down which commands are given, and up which corresponding reporting is expected.
- Dotted or broken rules indicate specifically designated lines of communication. For example the VP Manufacturing in Figure 8.1 is shown as having a particular need to communicate regularly with the accounts manager who heads Department E.
- Roles lying outside the line reporting structure are called staff roles. People in staff roles have no direct line authority, but can usually enjoy status and indirect power through the support of their line manager. The secretary in Figure 8.1 is in a staff role without any personal power, but any person in the organization who is sufficiently misguided to treat that secretary without due respect would risk incurring the wrath of the president.
- People doing the most menial administrative or janitorial tasks are not usually shown.

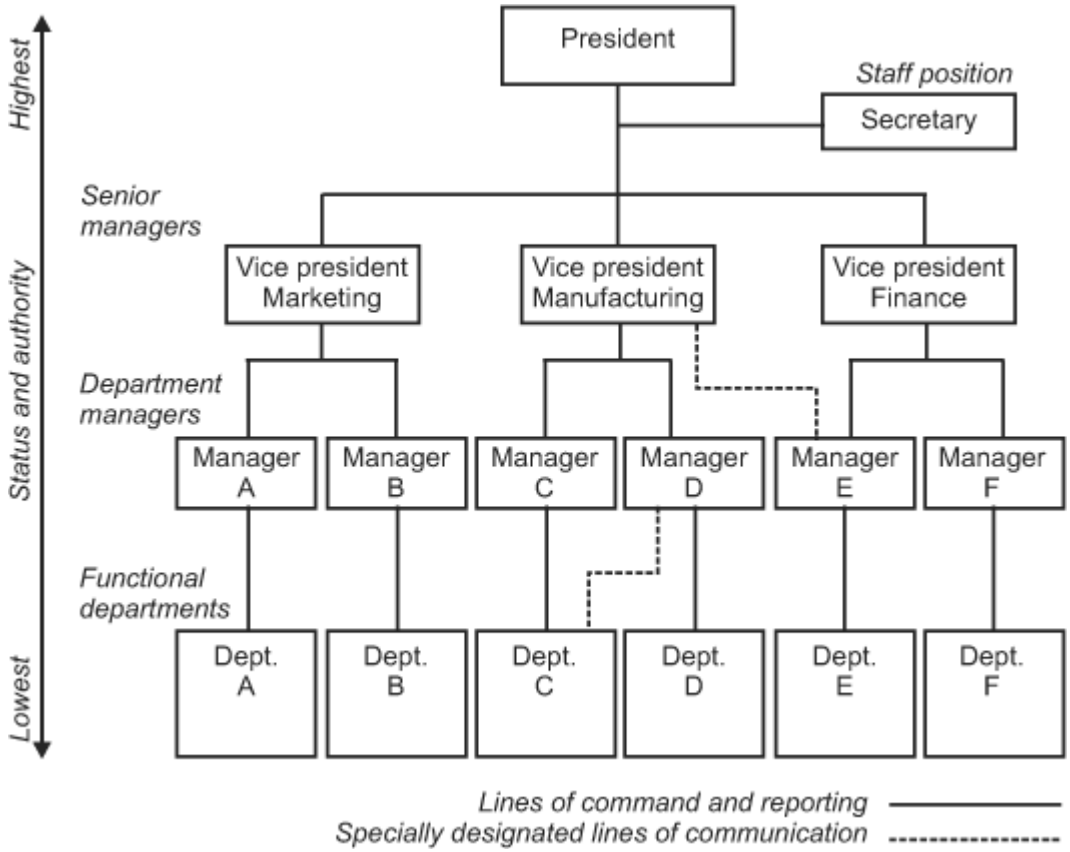


Figure 8.1 Organigram conventions. The organization depicted is line and function

Limitations of Organigrams

Inability to show complex communications and influences The principles listed above might seem logical and clear. However, in practice organizations are far more complex. For example, in all except the most outdated, authoritarian, militaristic organization structure, informal lines of communication and feedback run up, down, sideways and diagonally across the organization. That's no problem and is usually to be encouraged. Organizations thrive on fast and effective communications, whether they are electronic or face-to-face. But no organigram can show every possible communication channel or define every subtle influence that one person might be able to exert over another.

If it is necessary to chart all those subtle and complex lines of communication, there are other methods available such as string diagrams. However, these depend on data from detailed observation studies, they are

not simple to draw and they can also be cluttered and difficult to interpret. Organigrams are a good compromise.

Unresponsive to changes An organigram, no matter how detailed, can only show the organizational structure of a company or project at a particular time. In many cases that poses no problem and some companies and project organizations remain stable for months or years.

We shall be describing different kinds of project organizations later in this chapter and, with some exceptions, a company matrix will be more stable than a project team. A team that is set up specifically for a project, either at a corporate head office or at an airport construction site, will change considerably as it progresses from birth to death throughout the project life cycle.

One solution to this difficulty is to draw the organization chart so that it depicts the project when the organization is at its greatest. Thus, even near the beginning of the project life cycle it will show the organization as it is expected to be when the project workload is at its peak. As the project nears its close people will understand that the chart contains roles that have served their purpose and disappeared. On a large project with long duration it may be necessary to issue revised organigrams several times.

Organigrams as sources of dissatisfaction or conflict When an organization structure changes or a new project is started it is wise and customary to produce a new organigram and distribute it. But that apparently simple process, however innocently intended, can provoke strong and unexpected reactions. Some employees will feel aggrieved when they find that their names are not included on the chart. They will view that as a personal affront and feel that they have been overlooked, or that their job is not seen as being sufficiently important.

The issue of a new organization chart can also give rise to feelings of envy or injustice when individuals feel that their particular box should be have been placed higher up in the hierarchical pecking order. At least one company attempted to solve this problem by issuing circular charts, with the different levels occupying concentric rings and with the company president at the center. However that is a not really a solution, because those nearest the outer rim of the circle might feel that they should be closer to the center.

Accepting the shortcomings of organigrams In spite of their limitations and potential for causing individual discontent, organigrams are the best practicable way of depicting an organizational structure. They are, in themselves, a form of communication, both within the company and as a tool to inform project investors, customers, regulatory bodies and other external organizations.

INTRODUCTORY OBSERVATIONS ABOUT ORGANIZATION IN PROJECT COMPANIES

Ancient monuments from earlier civilizations demonstrate that project organizations of some kind must have existed for thousands of years. However; modern company organizations generally have their origins in the formal hierarchical structures of the military and the church. Ever since the early 1900s, management theorists have devoted their lives and work to exploring and attempting to explain the effects that different organizational structures can have on people's motivation and company performance.

Communications in the Organization

Good management communications demand adequate feedback paths through and across the organization. These allow progress to be monitored, difficulties to be reported back to executive management and expert specialist advice on technical or commercial problems to be sought and given. The principal communication paths will be apparent from the charted organization structure, through the vertical lines of command and reporting. However, cross-departmental lines of communication develop in all organizations which do not show up on any chart, yet are important in achieving a cohesive and productive organization.

Every modern business depends tremendously on communications. A good company culture needs daily interaction and communication without hindrance across all its functions. Ad hoc lines of communication cannot all be shown clearly on an organization chart but they are nevertheless vital to project management and help to encourage a friendly, cooperative and productive work environment.

Dangerous formality It is convenient here to give a short account of how not to manage communications between people and departments within a company. Senior managers in long-established companies once had strict ideas about internal communications, motivated to some extent by fear of the unknown and their determination to keep power close to themselves. Those managers demanded that all commands and resulting feedback should be vertical, through the charted lines of command. They preferred, even insisted, that communications between individuals from different functional departments should be routed through the departmental managers (up and down along the lines of command in the hierarchical power structure). People in one department were actively discouraged from communicating directly with people in other departments. Uncharted lines of communication were disliked because they could not be controlled, and did not conform to a tidy idea of company procedures. It may be that such companies still exist. One of us, in his more junior years, had the misfortune to suffer the frustration of working in such an organization. Then the company engaged a competent management consultancy to advise on its organization and operations. One direct result was that the formal communication barriers were removed. The effect was like opening windows and letting in the fresh air of springtime. An immediate and pronounced improvement in morale resulted. People felt that they were more respected as individuals and their sense of personal esteem was enhanced. More to the point, the company's project performance improved too.

Choosing the Ideal Organization

Every business has its own ideas about how to organize itself and its work. It is highly probable that if three businesses doing similar work could be compared, three different organization structures would be found. Further, all three businesses might be successful, implying that it is not always possible to declare firmly that there is one best organization solution.

This chapter cannot, therefore, dictate exactly how every project should be organized. Instead, we describe possible organization structures and list their advantages and disadvantages. We recognize that some organizations can be ideal for one project but highly unsuitable for another. We shall set out some of these characteristics so that readers can judge which might be appropriate for their particular project circumstances.

For many people working in projects these arguments are academic, because most project managers are appointed to an organization that already exists and they are given no authority to change it. Power to create organizational change is usually owned by senior company management, so perhaps it is they who should be reading this chapter. But to any person or group given the responsibility of establishing or changing any organization structure we strongly offer the following advice:

Think of yourself as being a more junior member of the project organization that you intend to create. Do that repeatedly for two or more different roles. Perhaps you might be a technician working within a functional group. Alternatively you could be a junior manager leading a small department. Imagine, as vividly and realistically as you can in each of those roles, how you would deal and react on a daily basis with your peers and superiors. Think how those relationships would affect your morale and sense of self-esteem. Think also about where your work instructions would come from, and whether you would have one source of instruction or could possibly have conflicting instructions from two or more different superiors. Where could you go for help if you run into technical or personal difficulties? If you have the power to choose the project organization structure, taking time out for that imaginative experience might help you to make the best choice.

COORDINATED MATRIX ORGANIZATIONS

Figure 8.1, apart from being included to demonstrate the features of an organigram, happens to be a line and function organization. Thousands upon thousands of small manufacturing and other companies that do routine work are organized along such lines. However, what would happen in such a manufacturing company that was asked to design and make a one-off product that required innovative design, special purchasing, bought-in parts, bespoke manufacturing, complex assembly, inspection and testing? That company would find itself in some difficulty because this new venture is a project that needs someone to drive it horizontally through all the different company departments. The line and function organization is essentially vertical, with no real horizontal component.

So the wise thing to do in those circumstances is to appoint a coordinator whose sole job will be to follow that special job through all the departments

and stay with it until it is delivered to the customer. If the company does that, it has recognized that the special job is, in fact, a small project and the special coordinator is a kind of project manager. The following fictional case presents this argument in more detail.

Case Example: A Coordinated Matrix Organization at Lox Airparts Inc

Execjetair Inc, (known as EJA), the manufacturer of a successful small twin jet executive aircraft, received a customer's order to design, make and deliver a fleet of six aircraft to a slightly modified design that would increase the operating range at the expense of reduced payload (including a reduction from eight to six passenger seats). EJA immediately recognized one requirement, which was the addition of the two auxiliary fuel tanks, each to supplement one of the two existing tanks. All fuel tanks were enclosed within the wings. The new auxiliary tanks were to be mounted in space newly created within each wing, and the port and starboard tanks would be designed as mirror images of each other. Thus, for the fleet of six aircraft, the minimum initial requirement was for six port tanks and six starboard tanks.

EJA issued a simple invitation to tender for the design and manufacture of these 12 fuel tank assemblies, each comprising a double-skinned aluminum tank with internal baffle plates. The tanks were to be supplied fitted with mounting lugs and fuel pipe connections, and holes had to be drilled to take instruments. EJA issued a general arrangement sketch of each wing, cut away to show the exact shape, mounting position and all connection requirements for the port and the starboard tanks.

By far the lowest bid was received from Lox Airparts Inc, (LAP) a company with a good reputation for supplying routinely manufactured small precision aircraft components and replacement spare parts as sub-contractors to several aircraft manufacturing and maintenance companies. LAP ordinarily carried out practically no creative design work itself but worked from drawings and manufacturing instructions provided by their customers.

LAP were delighted to win the contract for these 12 tanks, but they had made this contract with EJA at a selling price set below the estimated design and manufacturing costs. LAP's business strategy in this case was to deliberately accept a loss as a means for buying into a new area of the components market, thus expanding capability and product range.

The existing line and function organization at Lox Airparts Inc Figure 8.2 shows the line and function organization of LAP just before the contract with EJA was signed.

This is a typical line and function organization in which the lines of command (and their corresponding upward reporting lines) are predominately vertical. Although ad hoc horizontal lines of communication will inevitably develop between the various functions and the staff, no formal provision has been made for these in this particular organization. Thus it is a particular example of the kind of organization depicted in Figure 8.1.

Emergence of a coordinated functional matrix at Lox Airparts Inc Planning and coordination difficulties arise when a company with a line and function organization encounters its first project. Senior company managers are accustomed to looking down their own lines of command into departments that perform routine functions. But a new project is a cross-functional operation that demands horizontal as well as vertical commands and communications. No person in this existing line and function organization has the time, the skills and the assigned duty needed to plan a project as a whole entity and follow that entire venture through all the stages of its life cycle from design to packing and dispatch.

Fortunately, LAP senior managers were aware of this shortcoming in their organization. They overcame the difficulty by appointing a temporary project manager with specific responsibility for planning and coordinating the EJA fuel tank project. The new organizational arrangement is shown in Figure 8.3.

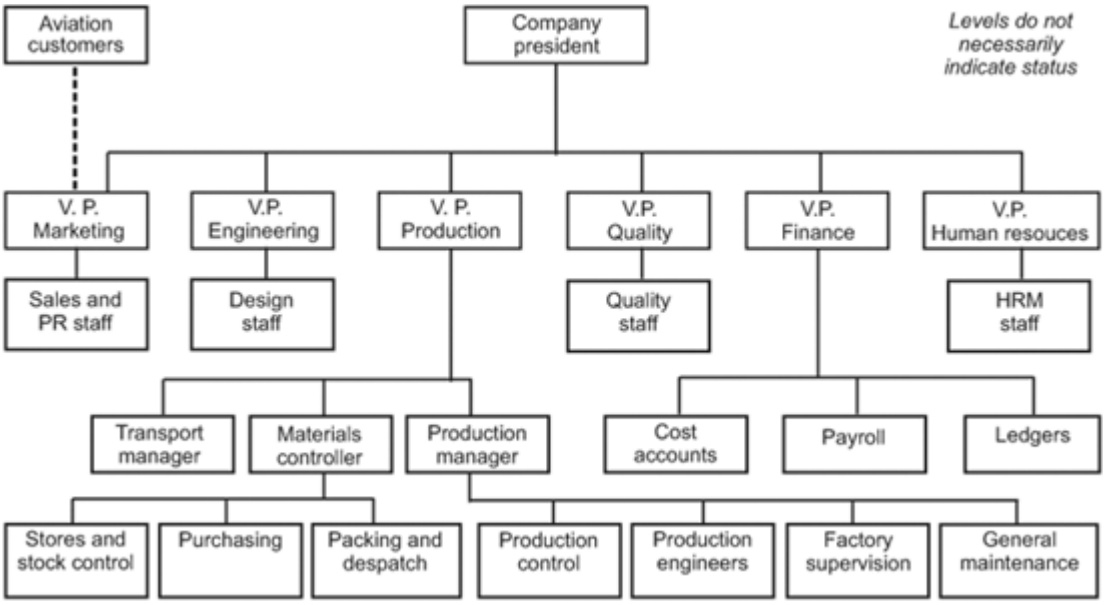


Figure 8.2 Outline organization of Lox Airparts Inc before the EJA fuel tanks project

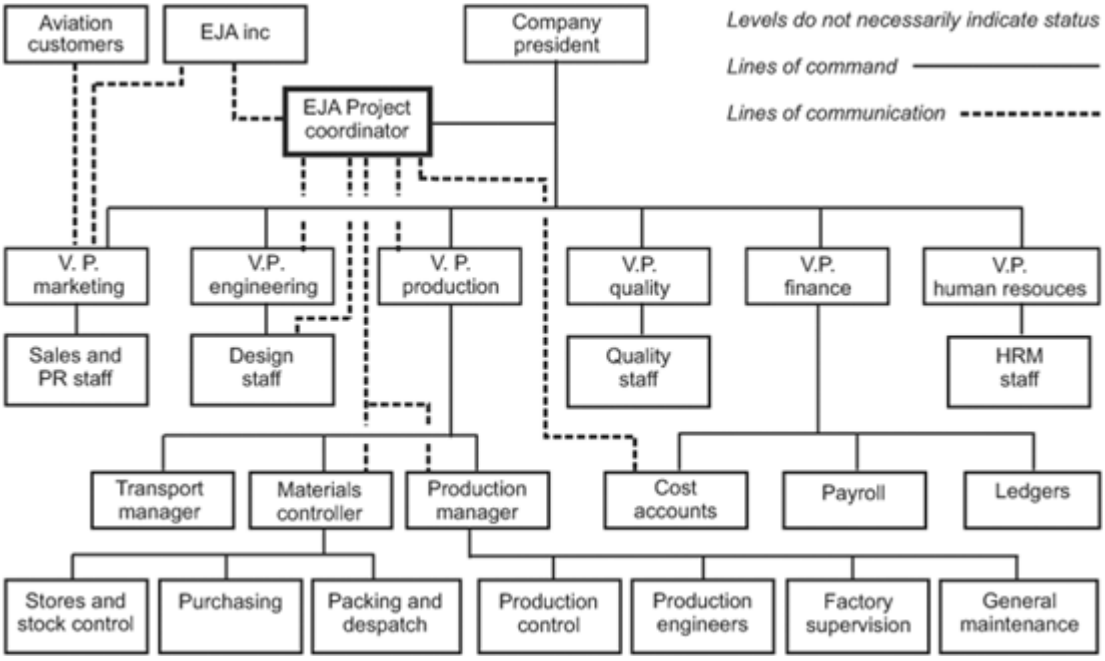


Figure 8.3 Coordinated matrix organization of Lox Airparts Inc during the EJA fuel tanks project

The new arrangement is an example of a coordinated matrix organization. The project coordinator must have the necessary skills to plan a project, issue schedules and then monitor all the project tasks to ensure that they are carried out within the required timescale and, as far as possible, within their

cost budgets. This is a temporary organization that will revert back to the former line and function structure unless, of course, LAP receive further orders for projects. It has the big advantage of being effective for the single project, yet will cause no disruption in the company when the project ends and the company reverts to its former line and function arrangement.

In this coordinated matrix the project manager has no line authority. Coordinators can only request that project tasks are carried out according to the schedules that they produce. Thus the job title 'project coordinator' more accurately describes this role and is often used in preference to project manager. Organizational theorists would call this a staff position in a line and function (or line and staff) organization. If the functional managers ignore the project manager or argue among themselves, the project coordinator's obvious remedy is to appeal to senior line management for help or arbitration. The position has some similarity with that of the secretary to the company president in Figure 8.1. The secretary has no personal power or authority, but other personnel usually have the commonsense to treat the secretary with due respect because failure to do so would call down the president's wrath.

A coordinated matrix has the big advantage that it is very easy to establish and calls for no fundamental change in the existing company organization. It is not disruptive. When the solitary project is over, the company simply carries on as before (except that it must decide what will happen to the project coordinator, who will then be without a project and without a job).

The duties of the project coordinator at LAP in this case example can be listed as follows:

- assimilate all project requirements by studying the EJA specification for the port and starboard tanks and the purchase contract;
- establish liaison with EJA, and thenceforth become LAP's principal point of contact for this project. This should help to create good communications between the two companies;
- plan the fuel tanks project, using critical path network analysis, and obtaining the input and agreement of all key project personnel within LAP;
- with the same key personnel who assisted with planning, estimate the project costs and establish project budgets for the individual tasks and for the functional departments;

- using suitable software, convert the network plan into work-to lists, one list for each functional manager involved in the project. If considered necessary, carry out resource scheduling at this stage. Each work-to list should be filtered so that it contains only tasks that are the responsibility of its particular functional manager;
- monitor the progress of every active task through all stages from initial work instruction to completion;
- attempt to re-plan or otherwise contain any time slippages, especially on critical tasks;
- report immediately to higher management any slippage that is in danger of delaying project completion and delivery of the fuel tanks;
- by collaboration with the cost accountant, monitor task costs again relevant budgets;
- ensure that any request for a design modification is critically examined and considered by key project staff before it is allowed (there is more on this important subject of managing changes in Chapter 23).

MATRIX SOLUTIONS FOR MULTIPLE PROJECTS

When a company handles several projects simultaneously, it can appoint a coordinator or project manager for each project. But if the individual projects are small, one person can be assigned to coordinate or manage two or more projects. A company that regularly has many projects in progress might appoint a projects vice president or director to oversee the individual project coordinators and their projects.

Sometimes a project support office is set up that includes planners, estimators and cost engineers, and progress chasers. A project support office might typically work as a department alongside the matrix and its manager would report to the projects director.

The matrix arrangements for a main contractor that regularly undertakes civil engineering or construction projects will be different from those of a manufacturing company. One important difference for construction and civil engineering companies (together with their associated professions such as architects) is that practically all their work is to do with projects and no new order is a routine repetition of past work.

Figure 8.4 shows a notional multiple project matrix structure for a construction company (which might include some aviation construction projects within its work portfolio). This kind of matrix is also seen in companies engaged in petrochemical, mining or other large capital projects.

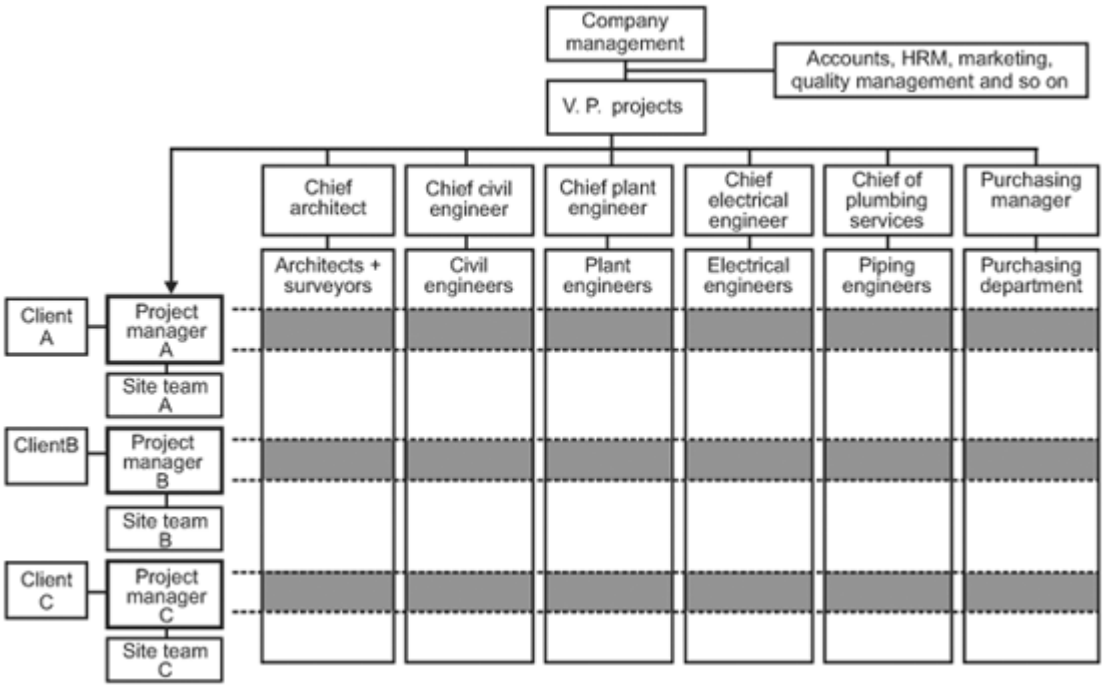


Figure 8.4 Outline of a matrix organization for a large contractor engaged in civil engineering and construction projects (including airport facilities and buildings)

Different Matrix Strengths

By no means is every matrix organization a coordinated matrix in which the project manager (or project managers) act merely as coordinators without line authority. The way in which power is apportioned between project managers and the various departmental managers can vary considerably from one company to another. Organization charts cannot show all the subtle nuances of power, and Figure 8.4 does not show how power is distributed between the project managers and the functional managers. Thus the chart in Figure 8.4 remains valid for all the variations of the matrix that will now be described.

Weak matrix A weak matrix describes any form of matrix organization in which the project manager's power is very low compared with managers of

the specialist functions. Thus a coordinated functional matrix is an example of a weak matrix.

Balanced matrix The balanced matrix provides for a balance of power and authority between the project managers and the functional department managers. All managers are expected to work together harmoniously and make joint decisions (for example on the allocation of resources). This is a common form of matrix and is elegant in theory. However, it depends on universal goodwill, which does not exist in all companies, and is thus not an ideal solution for every project case.

Strong matrix In a strong matrix the authority of the project managers is greater than that of the functional managers, at least as far as work allocation and progressing is concerned. The intention is that the functional managers nominate members of their departments to work for the project managers on specified projects. The people assigned report principally to the project managers (although they might remain physically located in their home departments).

The very strongest matrix form is the secondment matrix, where functional managers must release nominated members of their staff completely to work for project managers for as long as they are needed (which might involve temporary physical relocation of the staff concerned).

PROJECT TEAM ORGANIZATIONS

It is, of course, possible to arrange things differently from the matrix options described above. A complete work group or team can be created for each project as a self-contained unit with the project manager placed at its head. The project manager is given direct line authority over the team.

The example shown in Figure 8.5 is a project team organization that might be set up for the main contractor of large construction project (which could include an airport development project). The project manager is in direct command, with complete authority over the team members.

Communications across the various technical and professional disciplines are easier and faster in a team when compared to a matrix. All members of the team identify with the project and can (at least in the short term) be strongly motivated towards achieving the project goals.

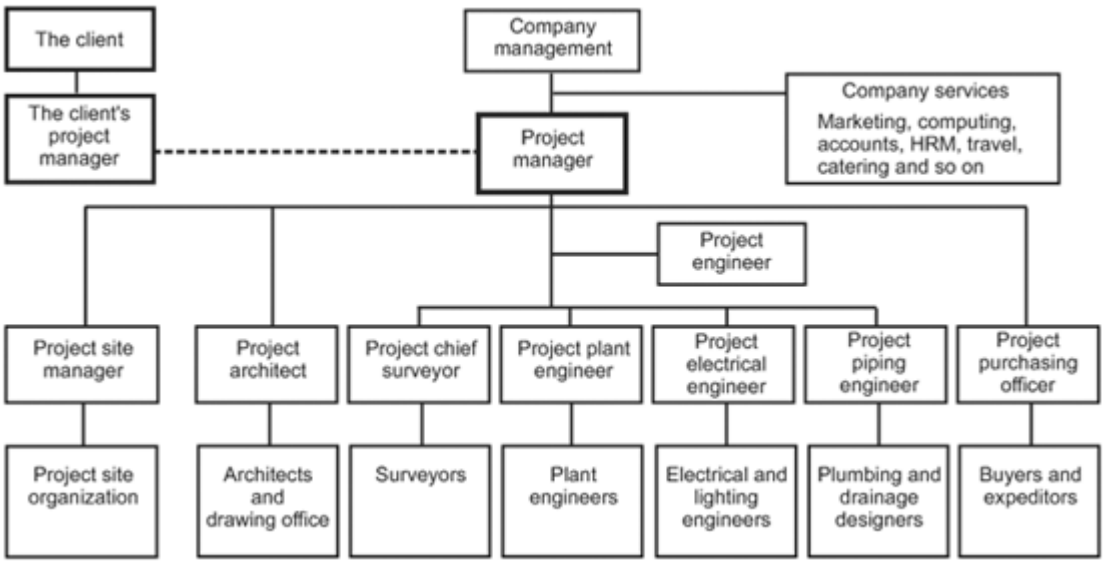


Figure 8.5 A possible project team organization for a construction project contractor

The key members of the team should preferably be located near each other, in the same building if possible. Ideally, an office should be provided for use as a 'project war room', where team members can meet formally or informally whenever they wish. Drawings, charts and plans can be displayed on tables and walls. War rooms should also be equipped with appropriate means for communicating with computer and communication networks.

Project Task Forces

A task force is an extreme form of a project team. It demands total dedication to the project, sometimes almost with fanaticism. A task force can generate the highest levels of motivation and appreciation of urgency. It is the ideal arrangement for rescuing a project that is in danger of running late.

The task force leader must possess very strong determination and drive. He or she should also be experienced in the project management arts: if not, it might be prudent to engage an external project management consultant, either to lead the task force or to provide urgent on-the-job training and guidance.

The task force members will work more effectively if they can be located together, away from their normal working locations, with an office that can be used as their project war room.

Task forces in aerospace manufacturing projects A self-contained project team might seem to be impracticable in a manufacturing company owing to the capital invested in the general manufacturing facilities. Expensive plant cannot usually be allocated for task force use and set aside full-time for the project, no matter how urgent the work is.

This problem can be solved by including in the task force managers (or their senior delegates) from all the departments involved in executing the project. When the project demands the urgent use of scarce or expensive common resources, the task force members will have the authority to instruct their home departments to carry out the work as high-priority tasks.

Task forces in management change projects A task force has the advantage that its members can be housed together in secure accommodation where privacy or secrecy can be preserved. Most management change projects begin with studies that have to be kept confidential, to avoid creating unfounded but damaging rumors. This is especially important where the project might lead to company reorganization or relocation and redundancies. When a relocation project is being considered, it is inevitable that several different locations will be considered and it is important to keep these possibilities confidential if staff rumors are to be avoided. For example, before Boeing moved its corporate headquarters from the original Seattle site (established in 1916), three cities in widely different parts of the US were short listed. Dallas and Denver featured in the shortlist before Chicago was chosen.

The time for openness and consultation with staff in management change projects must come, but not until the results of a completed study have suggested one or more preferred solutions or business plans and removed much of the doubt.

A task force comprising senior delegates from all company departments that would be affected by the management change project can be set to work in a secure office, allowing the study work to be carried out in secrecy. When external consultants are engaged to lead the study, the presence on the task force of people who know their departments' operations intimately can prevent expensive and damaging errors and omissions in the proposed solutions.

TEAM OR MATRIX: WHICH ORGANIZATION IS BEST?

Team Pros and Cons

Project teams have the advantage that they can each be directed to the successful completion of one project. A team can be completely autonomous. It is provided with and relies on its own resources. There is no clash of priorities resulting from a clamor of different project managers in competition for scarce, shared resources.

An important aspect of motivation is the generation of a team spirit, in which all members of the team strive to meet common goals. It is easier to establish a team spirit when a project team actually exists (as opposed to the case where the people are dispersed over a matrix organization that has to deal with many projects).

If the work is being conducted for a government defense contract, or for any other project that requires a secret or confidential environment, the establishment of a project team greatly helps the organizers to contain all the work and its information within secure boundaries.

However, unless the project is very large, the individual specialist sub-groups within the team will be too small to allow optimum flexibility of labor and other resources. For example, where a specialist department in the organization employs 100 people on a project, the absence of a few workers through sickness might result in some rescheduling but would be unlikely to cause disaster. If, on the other hand, a project team had been set up to include its own independent specialist group, perhaps justifying the employment of only six people, the infection of three of these with influenza could set the project back by three weeks.

There is a danger that professional people working alone in small project teams are deprived of the benefits of working in a department with colleagues of their own specialist discipline. It is less easy for them to discuss technical problems with their peers or have access to the valuable fund of technical and professional data (historic and current) that such specialist functional groups accumulate.

Even if a project is of sufficient size to justify its own exclusive team, not all the problems of project coordination will necessarily be overcome. Very often it might be found impossible to house all the participants under one

roof, or even in the same locality. Although team organization might be logical and ideal for the project, a general lack of coordination between the functions is still a possible risk.

A big problem with a project team organization is realized when the project end is in sight. Team members will have concern about their future work, or indeed whether or not there will be any future work for them at all. That concern is a powerful demotivator and can lead to a slowing down of work in an attempt to delay project completion and put off the evil day.

Another possible danger with a team is that something could go seriously wrong with the project after its supposed completion, with expert attention required from the team's engineers to satisfy the customer and put matters right. If the team no longer exists, and the engineers who designed the project have been dispersed, events could take an embarrassing, even ugly, turn.

Matrix Pros and Cons

The matrix option allows the establishment of specialist functional groups which have 'eternal life', independent of the duration of individual projects. This continuity of work promotes the gradual build-up of expertise and experience. Specialist skills are concentrated. Pooling of skills provides for flexibility in deploying resources.

Each member of every specialist group enjoys a reasonably stable basis for employment (provided the order book is full). There is a clear promotion path within the discipline up to at least chief engineer level, and each person in the group is able to compete against his or her colleagues for more senior positions within the group as vacancies arise in the long term.

Performance assessment of each individual, and any recommendation for promotion, improved salary or other benefits, is carried out by a chief engineer or other manager of the same engineering discipline within the stable group. This is more likely to result in a fair assessment and employee satisfaction. These possibilities are not readily available to the specialist engineer working alone in a multi-disciplined project team.

The matrix organization has its own characteristic disadvantages. Not least of these is the split responsibility that each group member faces between his or her functional line manager and the project manager in a balanced matrix. Employees are expected to serve two managers. Personal stress and conflict will arise if an individual receives conflicting instructions

from the project and functional managers. That violates the long established principle of unity of command.

Characteristic	Organization indicated	
	Team	Matrix
Maximum authority for the project manager	✓	
Freedom from duplicated or ambiguous lines of command	✓	
Maximum motivation of staff to meet difficult targets	✓	
High security of information: by enclosing work in secure areas	✓	
High security of information: by restricting the number of staff who need to know about the work	✓	
Most flexible deployment of resources		✓
Most effective use across the company of those with rare specialist skills or knowledge		✓
Large project, employing many people for a long duration	✓	
Several small simultaneous projects, each needing a few people for a short time		✓
Career motivation of individuals: opportunities for promotion within a person's specialist discipline		✓
Career motivation of individuals: through long-term continuity and relative stability of the organization		✓
Post-design support to construction or commissioning staff		✓
Efficient post-project services to the customer		✓
Establishment of 'retained engineering' information banks from which future projects can benefit		✓

Figure 8.6 Project team characteristics versus a balanced matrix

Summary

So, team or matrix? The arguments will no doubt continue as to which is the better of the two organizations. Some of the pros and cons are summarized in Figure 8.6. As a general guide, large projects of long duration will probably benefit from the formation of project teams. Matrix organizations are

indicated for companies that handle a number of small projects in which neither the amount of resources nor the timescale needed for each project is great.

HYBRID ORGANIZATIONS

Sometimes companies adopt a hybrid organization, operating a matrix organization in general, but with teams set up for certain projects when the need arises.

An example of such a hybrid organization is shown in Figure 8.7. This shows the same contracting company that was illustrated in Figure 8.4. That company was organized originally as a matrix. However, now it has just signed contracts for two new projects, each of which will require only one of the specialist functions from the whole matrix.

Project D is for the repair of Runway 27 at XYZ airport. This runway has suffered cracking and surface deterioration and is in urgent need of repairs. However, it is the main runway at the airport and works can only be carried out at night. A task force is the ideal organization for seeing this project through to completion as soon as possible, and the obvious home for that task force in the contractor's organization is in the civil engineering group.

Project E is to replace the runway lighting, some of the cabling, and the control tower switchgear at ABC airport. To keep the airport operational, the project manager will arrange for the lights to be replaced six at a time, during non-operational night hours. This will continue until eventually all the lights have been renewed. The switchgear changeover can be made during daylight hours, picking a day when there is bright sunshine. This project has no particular urgency, but it must be carefully planned to avoid operational disruption. Clearly this project can be organized as a team contained entirely within the electrical group.

So this contractor's matrix organization has now become a hybrid, in which the original matrix organization has been supplemented by two specialist, custom-made project teams.

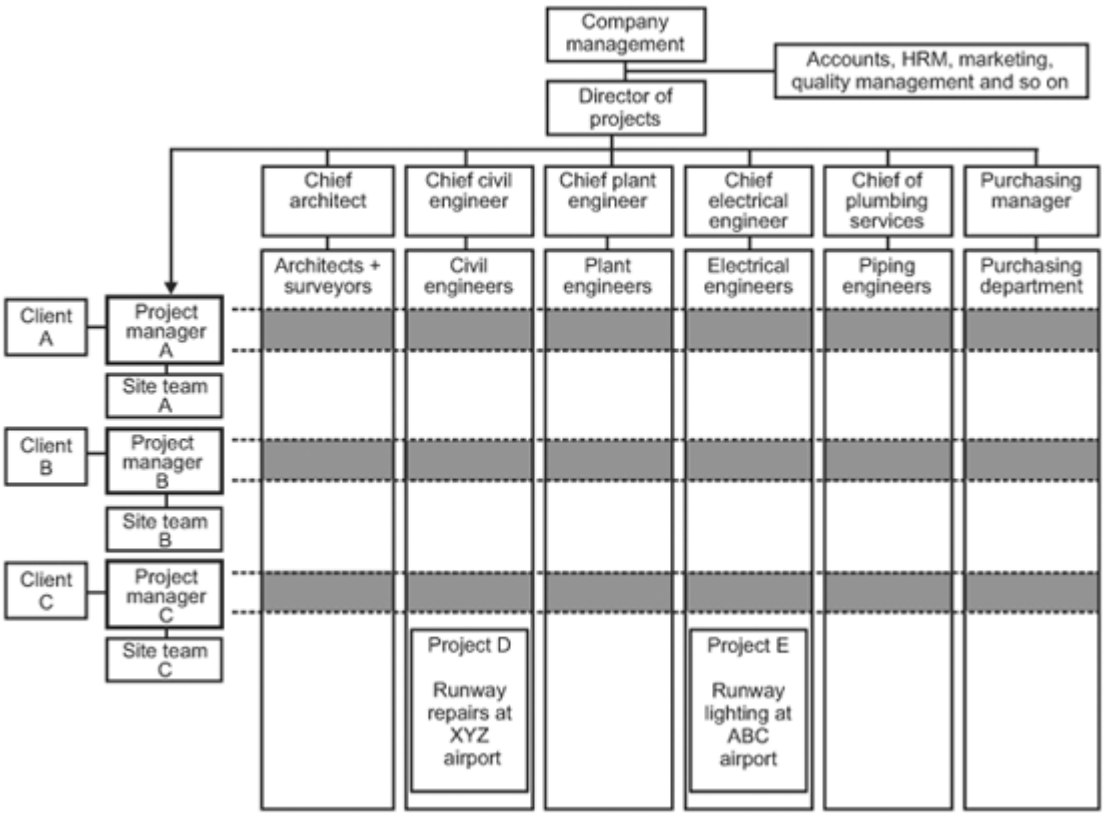


Figure 8.7 Outline of a hybrid organization for a large contractor engaged in civil engineering and construction projects (including airport facilities and buildings)

CONTRACT MATRIX ORGANIZATIONS

In large aviation construction projects the customer/supplier chains can form a contract matrix. In the example shown in Figure 8.8, the project owner (the customer or client) has engaged a managing contractor to design the project, carry out purchasing, hire subcontractors and generally manage all the activities at the airport site.

The organigram shows that many of the companies involved in the project will have their own project managers, in addition to the principal project manager employed by the main contractor.

This project is being funded by a bank, which has lent funds on condition that the project owner finds a guarantor who is willing to underwrite a substantial part of the lending risk. In the UK, for example, the Export Credits Guarantee Department (ECGD) acts as guarantor for some projects carried out for overseas clients, whilst the Export-Import Bank (Ex-Im) fulfills a similar role in the US.

Both the bank and the guarantor need expert independent advice. This has been provided in the example of Figure 8.8 by a professional engineering organization. This organization, sometime known simply as 'the engineer', can inspect progress and certify all significant claims for payments so that monies are only paid against work that has actually been performed correctly and in the quantities listed on the contractor's invoices.

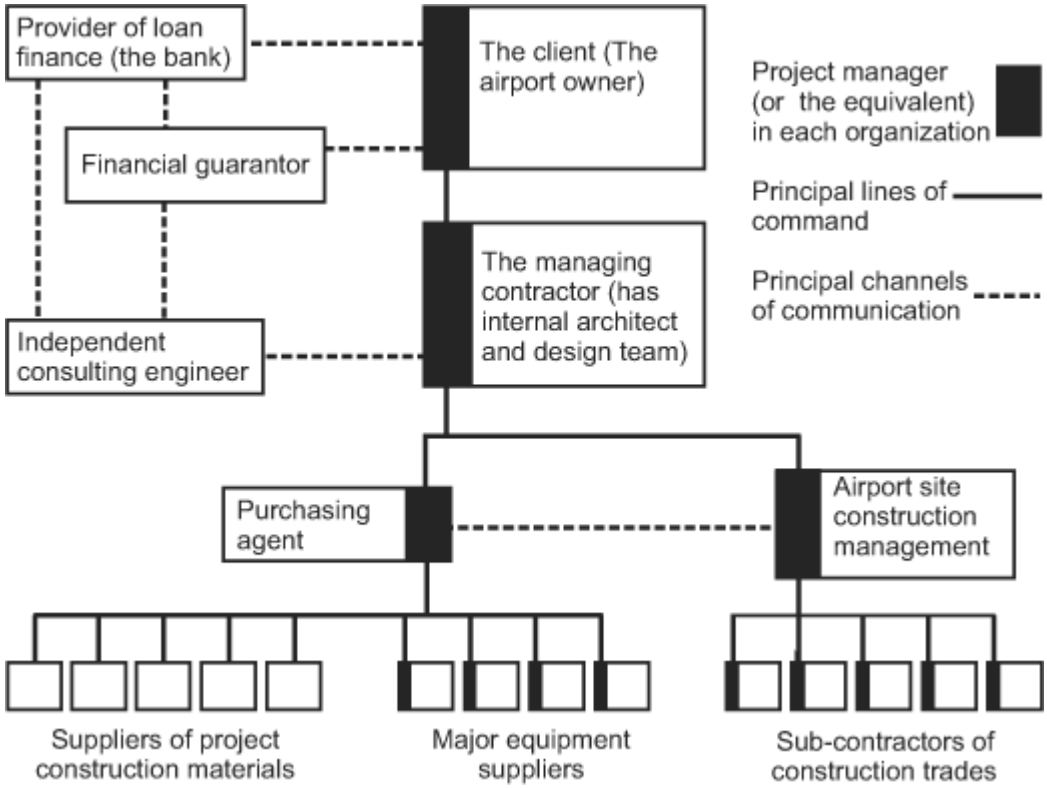

Provider of loan finance (the bank)
The client (The airport owner)
Project manager (or the equivalent) in each organization
Financial guarantor
Principal lines of command
The managing contractor (has internal architect and design team)
Principal channels of communication
Independent consulting engineer
Purchasing agent
Airport site construction management
Suppliers of project construction materials
Major equipment suppliers
Sub-contractors of construction trades

Figure 8.8 A contract matrix organization for an airport construction project

JOINT VENTURE PROJECTS

For very large projects several companies might agree to combine their resources and share the technical problems, expense and risk by forming a consortium or joint venture company. This approach will add yet another complication to the organization and at least one more project manager.

Many aviation projects, such as the design of large passenger aircraft or sophisticated military and naval aircraft involve such a wide range of different technologies and such vast investment (and risk) that a joint venture or consortium organization has virtually become the norm. These

organizations span not only several different companies, but also international borders, with all the difficulties of language differences and cross-border engineering standards compatibility. However, for aerospace manufacturing companies such as Airbus, and more specifically with the A-330F project most recently, a joint venture structure seems to provide an integrated base from which to reach for longer-term strategic goals. Early in 2008 Airbus announced a commitment to establish an A330 Freighter aircraft final assembly line in Mobile, Alabama if Northrop Grumman (supported by Airbus's parent company, EADS-European Aeronautic Defence and Space Company) received the order to build aerial refueling tankers from the United States Air Force.

An outline example of a joint venture organization is given in Figure 8.9.

For any complex project, apart from the obvious need to define responsibilities and all the contractual details, it is vital that the lines of communication between all the parties are clearly established and specified. It is not unusual to find projects where the participants are separated by thousands of miles, working in countries with different engineering standards. The project manager will have to plan for details such as working with companies that have different national working practices, workdays and holidays. The volume of information for a large project, whether in the form of drawings, other technical documents, commercial correspondence, queries, and even hotel and travel arrangements can be mind-boggling.

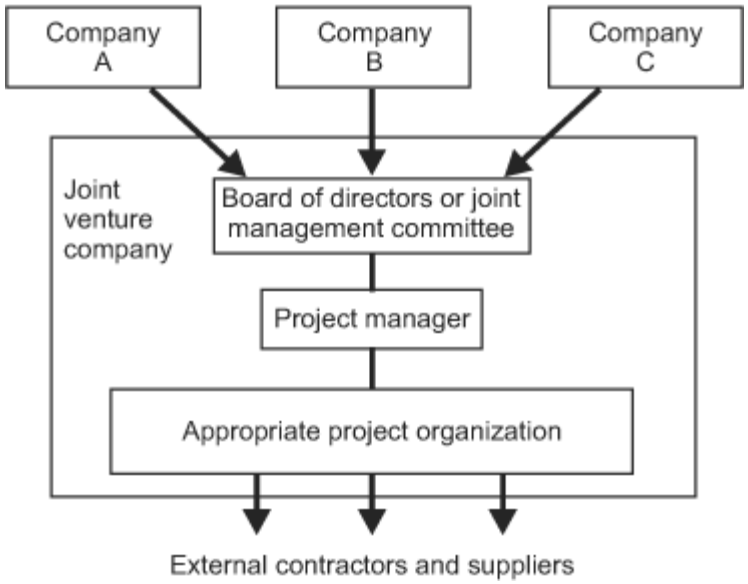


Figure 8.9 One form of a joint venture organization

9
Some Key Roles and Stakeholders in the Project Organization

Chapter 8 outlined some of the organization structures that are peculiar to projects. Hundreds, even thousands of people might work directly on a large aviation project and many will have some part to play in its success or failure. There will also be stakeholders who, although not part of the workforce, can play a decisive role in the project outcome. When we consider all the people and organizations that can influence the outcome of a project it is surprising that any projects are finished successfully and little wonder that so many fail. Clearly the project manager plays a pivotal role, at the hub of all the activities and with a great deal of responsibility for ensuring that all project tasks are performed when they should be performed, within budget and of acceptable quality. But the project manager cannot work unless given the appropriate organizational and financial conditions. For those conditions to be satisfied, we must look first to senior management.

THE ROLE OF SENIOR MANAGEMENT IN PROJECTS

Whatever the kind of project, and whether or not it is internally funded or carried out for an external customer, it is principally the senior managers who are responsible for the environment in which the project manager operates. It is senior management who are ultimately responsible for engaging, paying and training the permanent staff of the enterprise. It is usually they who define the organization, ensure that sufficient facilities and resources are available, step in to resolve conflicts and provide all the support functions on which every project manager depends.

Companies that operate a policy of paying their sub-contractors and suppliers as late as possible, or even not at all, will create difficult or impossible conditions for their project managers. The best working

relationships are those based on trust and working together for mutual benefit (the so-called win-win kinds of deals). Suppliers and contractors who do not get paid cannot be expected to give the project manager their support. This is an area in which senior company management policies and decisions can either support or hinder the project manager. Unless the company is in financial trouble and short of cash, senior managers should ensure that suppliers and sub-contractors get a fair deal and have their invoices paid on time.

Some senior managers unfortunately do not appreciate the importance of the project management function, even regarding it as an unnecessary overhead expense. In Chapter 1 we referred to Harold Kerzner's observations in this context (Kerzner, 2000). Project managers (including lecturers and writers such as ourselves) have a duty in this area by demonstrating to senior managers just how important the project management function can be, not only to projects but also to the wider success of the company. Those of us with the relevant experience should point to our past successes and, with supporting facts and figures and not a little pride, report how our past efforts as project managers or project management consultants have saved companies hundreds of thousands of dollars and brought their projects in on time, where overrun budgets and late deliveries were the previous norm. If senior management can be convinced that good project management will put money in the bank, then we might convert the skeptics and win their essential support.

THE PROJECT CUSTOMER (OR OWNER)

Many projects (such as management change projects and new product R&D) are, of course, carried out internally where the project owner or customer is, in effect, the company itself. However, in this section we have in mind any project carried out for an external customer. This is the person or organization that has accepted the contractor's offer to carry out the project and has entered into a contract accepting the contractor's terms. In return for paying the agreed price, this customer will expect either to benefit directly from the project or sell it on to an eventual end-user.

The main purpose of the project should be to satisfy the customer's project specification and contracted requirements, which brings back to mind the three primary project objectives of time, cost and specification introduced in

Chapter 2. Some people go further and declare, admirably, that we should set out to delight the customer.

However, the customer is not a passive stakeholder and its own role complements that of the contractor's project manager. The customer can, by its actions or failure to act, play a big part in the success or failure of a project. On a large project the customer might appoint its own project manager, to keep in regular communication with the contractor's project manager, safeguard the customer's interests, and also assist the contractor wherever possible by ensuring that technical and commercial issues are resolved expediently.

An ideal customer will:

- always have sufficient funds to meet the contract commitments;
- settle the contractor's legitimate claims for payment on time;
- sign off decisions without unnecessary delay (for example on drawings or major purchases);
- send a suitable representative to project meetings when invited to do so by the contractor;
- avoid unnecessary changes to the project;
- not attempt to interfere unreasonably in the contractor's established internal procedures
- support the contractor and present a 'united front' in dealings with regulatory bodies and other external bodies (including suppliers and sub-contractors);
- settle disputes by constructive negotiation rather than by litigation.

If the contractor's customer happens to be a government department (such as defense) some of the above conditions may not be fulfilled. Indeed there may be a severe element of risk to the project. The customer's strategies and actions can alter on the direction of politicians. National elections can be a stressful time for contractors working on government projects. Large defense projects have been axed suddenly by politically motivated government decisions. Even successful proving flights of a new military aircraft are no guarantee that the government will continue to support the project and buy that plane for its forces.

THE FINANCIAL INSTITUTIONS

Many large projects could not happen without the provision of funds from banks and other financial institutions. These are prepared to lend money with the expectation of being repaid with interest or, alternatively, of buying a remunerative stake in the project.

There have been many cases where projects have overrun their budgets by such large amounts that the banks have been called upon for additional funds. That leaves the banks with a dilemma:

1. Do we provide additional funds to keep the project afloat and increase our investment and risk?
2. Do we attempt to spread our risk by arranging (or by demanding that the contractor arranges) additional sources of finance by other means?
3. Do we cut our losses, pull out of the deal, and watch the project fail?

Managers of projects funded by loan finance will soon discover that the external provider of funds will take considerable interest in the internal progress of the project. Banks and other investors might wish to have some influence in the way that it is managed.

However, bankers cannot be expected to have expertise in the technical detail of aviation projects. They will need independent expert advice if they are to be assured that the funds which they provide are being properly applied. That detached advisory role is often provided by a professional individual or company that the funding contract will probably call ‘The Engineer’, a role that we describe later in this chapter.

THE DESIGN ENGINEERS AND MANAGERS

The designers in aviation projects, especially those concerned with aircraft design, face enormous challenges. Some airframe components have to be lightweight, have to withstand enormous stresses without failure, must be able to endure thousands of hours flight time and yet must be capable of being manufactured at costs which are economic.

Engineers are often accused of not having any commercial interest or acumen, being interested only in creativity and innovation. That may be partly true, but the good engineering manager will understand the principle of

total cost management, in which the total costs of design, materials and manufacture are taken into account to arrive at the most economic total cost for the project. This means close cooperation during design with those who will be responsible for manufacturing and assembling the components so that the design represents the best economic solution for the company—not just to achieve the lowest design cost.

THE PROJECT MANAGER

The organization structures described in Chapter 8 demonstrate that the levels of responsibility and authority given to project managers vary considerably from one organization to another. In some cases project managers act only as planners and coordinators, with minimal power and authority. In other businesses the project manager will have complete authority over all those responsible for achieving the project objectives.

The Project Manager as a Specialist

A popular and perennial debate persists about the technical background of the ideal project manager. One school of thought declares that anyone skilled in the arts of project management can manage any kind of project, in any industry and in any technological environment. Following this argument would imply, for example, that a person who has just successfully managed a project to design new air traffic control software could move on to manage the design and development of a new aircraft.

The other school of thought takes the opposite view. It argues that a senior design engineer or technical manager with suitable training and experience in the relevant branch of aviation engineering could manage a relevant aviation project successfully without any particular project management skills. Perhaps they will have some project management software on their computer, but no practical project management experience. Indeed, one software advertisement that we saw a year or two back declared confidently ‘If you can move a mouse you can manage a project’.

Although most project managers will be sufficiently qualified to understand both the technical and the administrative details of their projects, it is theoretically possible for a non-technical person to manage a technical

project provided that he or she has the inherent management skills. This principle is proved and exploited, for example, during 'action learning' programs. Action learning is a management development method developed by the late Professor Reg Revans (Casey and Pearce, 1977; Pedler, 1997 and Weinstein, 1998). In an action learning program, managers from different professions are switched between very different jobs for a few months under the supervision of a professional trainer. For example, a manager from a bank and an executive from an oil company might swap their jobs for a few months. Each knows little or nothing about the technology of their temporary job, but will have basic management skills. The individuals gain personally from their experiences, have their horizons extended and can return to their original jobs enriched. The participating companies gain from fresh ideas that the temporary jobholders bring in, possibly using lateral thinking.

A further dimension to specialism in project managers is added by professional bodies such as the Project Management Institute (PMI) which run their own accreditation and certification schemes. Members can obtain project management qualifications that go beyond purely academic degrees by requiring considerable evidence of training, experience and achievement in managing successful projects. Clearly a candidate holding the PMI's professional project manager (PMP) qualification would have a strong competitive edge over an unqualified rival.

The term 'specialist' can be misleading when applied to project managers, since much of a project manager's time will be taken up with coordinating the activities of project participants from a wide variety of administrative, professional, technical and craft backgrounds. This work, far from requiring specialization, demands a sufficient general understanding of the work carried out by those participants for the project manager to be able to discuss the work sensibly, understand all the commercial and technical data received, and appreciate (or question) any reported problem.

The Project Manager as an Administrator

The project manager should have a general understanding of administrative procedures as they will be applied throughout the project organization. Project managers who have to ensure a flow of project data between different departments should be able to use their understanding of the administration and its procedures to arrange for that information to be

presented in the form most likely to be helpful to its various recipients. In the jargon of computer technology, the project manager may be asked to solve interface problems, the solutions to which need some understanding of how the peripheral units operate.

One important branch of project management, particularly for large projects, is contract administration. As a large commercial aviation project proceeds, it will almost certainly attract many changes, both from the customer and from internal requests. It is very easy for a large project to become a financial mess if customer-funded changes are not properly agreed, recorded and followed up. This is all important administrative activity which, if not diligently performed, will lead to chaos and arguments concerning actions and payments.

In aviation projects especially, good administration is vital to retain the true as-built condition of projects, and of all parts or products resulting from those projects. This responsibility extends beyond the immediate project life cycle and remains as long as any aircraft or other product remains in service.

Much of the administrative burden can be loaded on to a project support office, but project managers must be ultimately accountable for their projects.

Seniority of the Project Manager

The questions ‘How senior is the project manager?’ and ‘To whom should the project manager report?’ now arise.

The person appointed will be expected to provide the company’s general management with relevant facts whenever it becomes necessary for them to exert their senior authority or take other executive action to maintain the project on its specified financial, technical and delivery course. The project manager should therefore have reasonable access to general management.

Much of the project manager’s time will be spent in coordination—steering and integrating the activities of some departments and relying on others for information or supporting services. This demands cooperation with and from the managers of most departments in the company, whether these departments are directly engaged in project fulfillment (such as engineering and production) or are service departments (like accounts and personnel). Ideally, therefore, the project manager should not be handicapped by being placed in an organizationally inferior position to any departmental manager in particular or to departmental managers in general.

Thus the desirable organizational status for the project manager appears to be indicated on a level at least equivalent to the company's departmental managers. This view is reinforced when it is realized that the person appointed will probably be called upon to supervise sub-contractors. For industrial and commercial projects, when the project enters its fulfillment phase it is the project manager who most often takes over from the marketing or sales department to represent the company to the customer. Thus the project manager is often a significant part of the corporate image that the company presents to the outside world.

Personality and Personal Characteristics of the Project Manager

What is the ideal personality specification for a project manager? One project manager might operate successfully by inducing fear and trepidation in his or her subordinates, so that every word is seen as a command to be instantly obeyed. Another might achieve the same results through gentle but firm persuasion. The essential element here is the ability to motivate people, by whatever means: seasoned experts will be able to vary their management style according to the response of the individual being managed.

The average project participant will appreciate being led by a project manager who displays competence, makes clear decisions, gives precise, achievable instructions, delegates well, listens to and accepts sound advice, is enthusiastic and confident, and thus generally commands respect by example and qualities of leadership.

Aviation projects often need vast sums of money. Financial acumen, by no means the strongest feature of all engineers and technicians, is an essential element in the project manager's portfolio of skills. The best project managers know that managing purchasing, sub-contracting and all internal work on time and within budgets is essential. They will know that so-called cost management techniques such as earned value analysis (although usually necessary for reporting to higher management) are carried out on historical data, principally to analyze trends and produce reports. They add costs to a project without adding value. It is only through timely actions to keep a project on track that the project manager will succeed.

Sometimes there will be bad days, such as when a customer requests and insists upon an unexpected change, a supplier goes bankrupt or a vital component fails on test after a passage of many weeks through the

manufacturing plant. Thus the project manager must also possess resilience, the strength to recover and initiate corrective actions.

Perceptiveness and the use of Project Information

Other essential characteristics of the project manager can be grouped under the heading of perceptiveness. Project managers must be able to spot the salient facts from a set of data or a particular arrangement of circumstances. They must then be able to use these facts to best effect by taking action or reporting important exceptions to executive management, whilst filtering out the unimportant and irrelevant material.

Most project managers will become accustomed to being presented with information that is incomplete, unduly optimistic, inaccurate or deliberately misleading. Therefore it is important that project managers should not be gullible. They will learn to check much of the information which they receive, particularly by knowing what questions to ask in order to probe its validity. As they gain experience they should become capable of assessing the reliability of individuals, departments and external organizations, so that they can apply 'confidence factors' to the data and stories that they provide.

Project managers of any merit will know the frustration caused, not only by receiving inaccurate information, but also by receiving no information at all. Data deficiencies can take the form of delayed instructions or approvals from the customer, late information from sub-contractors and vendors, and tardy release of design and other information within the project manager's own company. It can be difficult to obtain reliable and regular reports of cost and progress from far-flung project outposts, particularly where the individuals responsible feel themselves to be remote and out of range from the project manager's authority or are educated to standards below those of the more developed nations.

The ability to gather, assess and act upon relevant data is, therefore, another essential property for project managers. It is no good expecting to obtain the complete picture and manage a project simply by sitting behind a desk for the duration of the project. The project manager must take (and be seen to take) an active interest. Project managers should visit personally and regularly those parts of the organization on which their project is dependent (a process sometimes known as 'management by walking about'). It might be necessary for the project manager to visit vendors, sub-contractors, the

customer and a remote project location at suitable intervals to gather facts, resolve local disputes, generate enthusiasm or simply witness progress at first hand.

Current Awareness

New project management textbooks and new project management ideas emerge in profusion almost daily. There is no doubt that project management tools, techniques and philosophy will continue to undergo development and change for as long as we have projects to manage. Project managers must be prepared to keep abreast of this development, undergoing training or retraining whenever necessary, and passing this training on to other members of the organization where appropriate.

Some new developments will advance the practice of project management in general and others will not. Some practices and techniques will be more useful to a particular project than others. The shrewd project manager will have the capability to choose, use or adapt the management methods that are most appropriate for the particular project. The temptation to impose unsuitable methods on an organization for the sole reason that they represent the height of current fashion must be resisted. One can have too many procedures.

DIRECTOR OF PROJECTS OR PROGRAM MANAGER

A company that engages continuously in the performance of projects, and always has several projects running simultaneously, might choose to appoint a projects director to oversee all managers of individual projects. This projects director will ensure standardization of the best aspects of project management procedures across the whole company and will arbitrate in disputes. If the organization is a matrix, the managers of all the technical functions and the drawing office would most probably report to the projects director rather than to the managing director or to the general manager. If the organization is set up as one or more teams, then probably only the project managers would report to the project director

THE PROJECT ENGINEER

The term ‘project engineer’ has two quite different meanings. In both cases the role demands someone who is highly proficient in the dominant project technology. In one case the project engineer is internal to the company and reports directly to the project manager. The other kind of project engineer works as an independent adviser from outside the core project organization, typically as the engineer in a contract matrix (as shown in Figure 8.8).

The Project Engineer as a Senior Member of a Project Design Team

There are two possible principal reasons why a project manager might not be able to exercise fully all the necessary technical skills necessary to direct and approve the project design, and thus needs support from a project engineer:

1. the project manager, although a good administrator, does not have the relevant technical training and qualifications to understand every detail of the project design;
2. the project manager, although technically proficient, has so many management and administrative duties that he or she has insufficient time left to spend on detailed supervision of the project design.

In both of these cases the project manager needs continual and reliable expert technical support and advice. That role might be performed collectively by the various functional managers, each of whom will be expert in a particular engineering discipline. But the project manager still needs a single source of technical support, someone who can oversee the design and reliability aspects of the project and resolve any technical conflict between the different engineering disciplines. That role is often performed by a project engineer.

Whereas a good non-technical administrator might be able to act as project manager, the role of the project engineer is unequivocally technological. The project engineer *must* be highly proficient in the main technology of the project. In many cases it is the project engineer who will approve all designs and specifications and oversee the quality and reliability aspects of the project. Thus the project engineer can fulfill a very senior role in the project organization, as second in command to the project manager.

The Project Engineer in the Contractual Context

Some conditions of contract require that an independent, external project engineer be engaged to monitor design and progress. A bank that has advanced money to a project owner, a financial guarantor or insurance company, or the project owner itself, will often require that someone with relevant technical experience protects their interests by acting as an independent advisor. This role was explained briefly in the contracts matrix section of Chapter 8.

In construction projects an independent quantity surveyor is employed to protect the owner's interests by certifying contractors' invoices for progress payments. The engineer's role has some similarities but is wider, and the engineer will be expected to visit the project design offices from time to time to review the contractor's design progress and performance. The engineer will often have to certify the contractor's invoices to the owner (or a funding bank) for design stage payments. The role of the engineer is explained more fully in Marsh (2001).

PROJECT SUPPORT OFFICE

Unless the organization is too small to support the additional expense, it makes sense to support the project management function by setting up a central project management services group or project support office (Marsh, 2000). This group is staffed with people (not too many!) who are capable of taking on the day-to-day chores, which can include the following functions:

- project registration;
- planning;
- resource scheduling;
- cost estimating;
- cost reporting and cost control;
- issue of work-to lists;
- progress reporting;
- change coordination;
- earned value management;
- supervision of the company's project management computer systems;

• program and portfolio management.

A project support office can be used in most kinds of project organization from medium size upwards. The group can be a functional department within a pure project team, where it will serve and report directly to the project manager. If the organization is a multi-project matrix or a hybrid organization, the project support office can be established as one of the departmental functions.

For a company that handles a relatively large number of small projects, none of which is big enough to justify its own full-time project manager, the project support office can play a direct project management role, acting like the project coordinator in a coordination matrix. When the project support office has this coordinating role, its manager must be given sufficient seniority in the organization for the coordination and control to be effective.

A project support office concentrates a company's expertise in the techniques of project management just as any other functional grouping can enhance a particular professional discipline. Centralization helps to standardize project administration procedures across all projects in a company. A project support group can be the logical place in the organization from which to coordinate all parts of the project cycle, from authorization to closedown. It can perform procedures such as cost estimating, project registration, risk logging, planning, resource scheduling and change control. It is also a logical home for the tedious but vital function of contract administration.

Some powerful project management computer systems, especially those handling multi-project scheduling, are best placed under the supervision of specially trained experts. Those experts must have a good working knowledge of all the organization's projects and combine that with special training in using the system and safeguarding the integrity of its database and back-up files. A project support office is an excellent place in which to place that responsibility.

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10
Work Breakdown and Coding

Imagine yourself as a project manager, having to start a very simple project. You might begin with a task list (a kind of shopping list of what has to be done) and simply work down the list until the project is finished. That approach is fine for a small project, when the task list contains only 10 or 20 entries. But most aviation projects, even some of the simplest ones, contain hundreds of tasks and some will progress through many thousands of different tasks before they are done. Therefore, after familiarizing yourself with the project definition, your first job as the manager of an aviation project is to organize all these tasks in some logical way that will allow them to be planned in time (that is, scheduled) and allocated to all the various people and managers across the project organization. Put another way, we have already described the ways in which people might be organized to carry out the project, and now we have reached the stage in the project life cycle when we must consider how the work itself can be organized.

So, this chapter describes the work breakdown process, which means breaking the project down into manageable chunks from which work can be allocated to departmental managers and other members of the project organization. The resulting breakdown pattern is known as a work breakdown structure, which is always abbreviated to WBS.

THE WBS CONCEPT

The procedure for creating a WBS arranges and names project tasks similar to the way in which we allocate program files and data files to a tree of folders and files in a computer system. A logical WBS facilitates the allocation of tasks, costs, resource quantities, labor-hours and much more project data to files from where they can later be retrieved at will and processed as required. Thus the WBS is a powerful tool that provides a framework for project management control, project cost accounting, progress

and cost reports, and project management in general. No one makes the case for developing a project WBS more eloquently and with more passion than Stephen Devaux, who wrote:

> If I could wish but one thing for every project, it would be a comprehensive and detailed WBS. The lack of a good WBS probably results in more inefficiency, schedule slippages, and cost overruns on projects than any other single cause. When a consultant is brought in to perform in the role of 'project doctor', invariably there has been no WBS developed. No one knows what work has been done, nor what work remains to be done. The first thing to do is assemble the planning team and teach them how to create a WBS.
>
> (Devaux, 1999).

So, if a WBS is a logical, hierarchical tree of all the tasks needed to complete a project, the top level must be the project itself. The next layer or level down contains the main work packages or major tasks. Levels below that progressively get more and more detailed. All the day-to-day tasks and smallest project components are found at the lowest level of the WBS. This WBS concept is seen in the goes into charts that engineers and designers use when organizing their drawings, bills of materials and parts lists for products that have to be manufactured and assembled. The process applies to all significant projects, whether they are to design and build a small family car or a wide-bodied passenger jet. Construction and management change projects require their own WBS processes in exactly the same way.

Logical Interfacing and Completeness

In addition to regarding the work breakdown as a family tree, it is also possible to visualize it as a jigsaw puzzle, with every piece put in its right place and with no piece missing (Figure 10.1). This concept is useful on two counts:

1. It is important that when the work breakdown is produced every piece of the puzzle is included, with no piece missing to spoil the total picture. This objective is sometimes difficult to achieve, but the risks of omission can be reduced by the use of suitable checklists. Brainstorming is also very useful, particularly for a project with no similar predecessors in the organization (so that checklists cannot yet have been developed through experience).

2. A method must be found that clearly and simply identifies each piece of the puzzle and denotes its position in relation to all the other pieces. This objective can be achieved by giving each piece an identification number which, through the use of a carefully devised, logical coding system, acts as a locator or address. Coding systems are introduced later in this chapter.

WBS EXAMPLES

Some people find difficulty in constructing work breakdown charts and we have seen students' coursework in which work breakdown charts are confused with organigrams. We can understand such errors because in some cases the WBS will correspond at its upper levels with the managerial roles in an organization. However, the WBS must go into considerably more detail if it is to include every task in the project, or at least every item that needs to be manufactured or sourced. A few examples will help to explain how a WBS and its coding system can be created.

Outline WBS for an automobile development project

We have chosen to begin with this example because of its familiar subject. Most readers will own and drive automobiles. In practice any vehicle development project will occupy several years and cost millions of dollars, but we can imagine an outline WBS that will also give some clue to the various departments and engineering disciplines involved. Our example in Figure 10.2 is, of course, greatly simplified and restricted only to the upper levels. In this case the WBS corresponds fairly closely to the upper level of the designer's goes into chart for the vehicle.

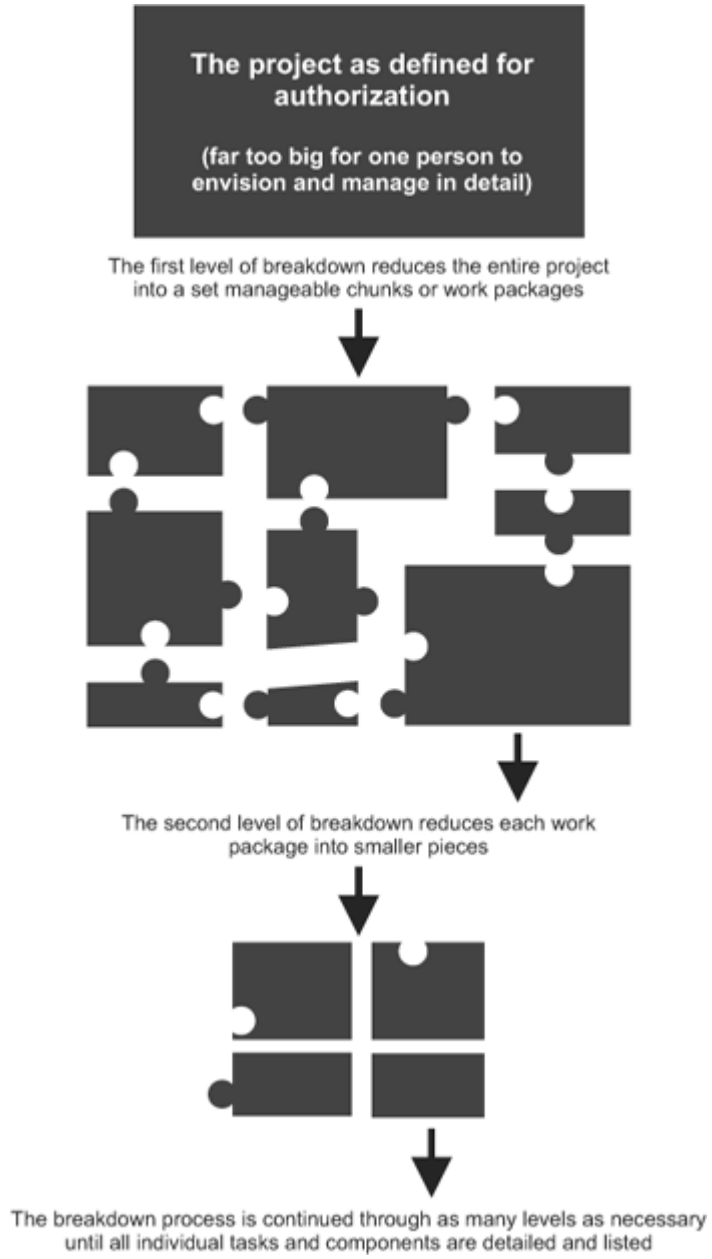

The project as defined for authorization
(far too big for one person to envision and manage in detail)
The first level of breakdown reduces the entire project into a set manageable chunks or work packages
The second level of breakdown reduces each work package into smaller pieces
The breakdown process is continued through as many levels as necessary until all individual tasks and components are detailed and listed

Figure 10.1 Principle of a WBS

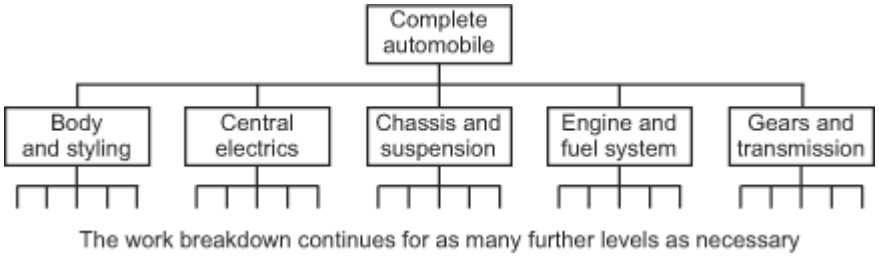

Complete automobile
Body and styling
Central electrics
Chassis and suspension
Engine and fuel system
Gears and transmission
The work breakdown continues for as many further levels as necessary

Figure 10.2 Simplified WBS for an automobile project

The WBS used during the development project will bear a very close relationship to the way in which drawings, specifications and instructions are arranged and numbered when the vehicle eventually goes into production .The original goes into chart will remain with the vehicle throughout its years of production, and beyond into the future time when customers take their cars in for service or repair (although it will be modified from time to time). Service stations will rely on database records that list all the parts with their code numbers, and we can be certain that these lists will still be structured according to the goes into chart that can be traced back to the original design and development project WBS.

Without that degree of logical formality and design discipline, any service station or mechanic would be hard pressed to track down and order a replacement for any one of the vehicle's thousands of components.

Outline WBS for a light twin-engined jet project

Again keeping our example very simple, Figure 10.3 shows how the initial WBS might look at the beginning of a project to design and build a light twin-engined jet aircraft. In this and in most other projects there will be considerable interaction between the design of the major work packages, and that can complicate the construction of a WBS. Also, there is often more than one way in which the project can be broken down into a WBS. However, Figure 10.3 does suggest a logical starting point for a breakdown that might eventually go down through many levels.

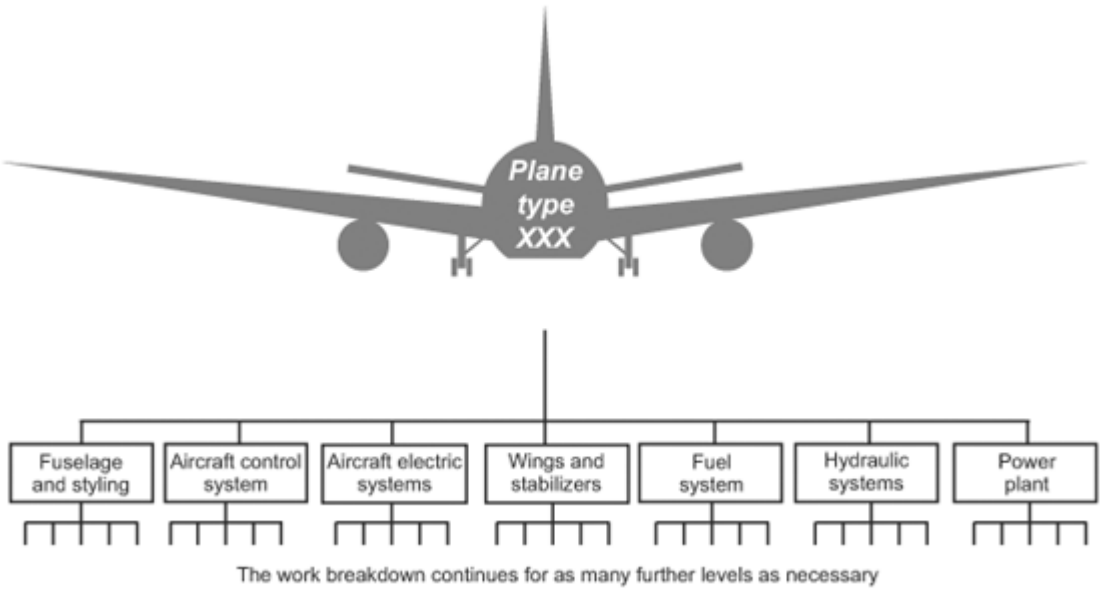


Figure 10.3 Greatly simplified upper level WBS for a light twin jet aircraft project

WBS for a project to set up a flying school

Suppose that a small group of businesspeople have combined their wealth and brains to establish a flying school for private pilots. Their company will be called The Loxville Flying School (LFS). LFS proposes to lease about 25 acres of land on the edge of a thriving small community airport at Loxville on which they will construct a training center, administration offices, hangars and maintenance facilities for the school's own small fleet of training aircraft. The project will also include building airside and public roads to connect the school to the airport and to the outside world.

In Chapter 1 we introduced four different types of projects and this flying school venture combines several sub-projects from two of those categories. Each sub-project that involves civil engineering, building construction and other site work will constitute a Type 1 project. Later, when the time comes to set up the school and its staff, it will evolve into a management project (Type 3).

The civil engineering and construction work packages are going to involve so much investment and work that each will probably be managed as a stand alone sub-project, allocated to one or more sub-contractors. Each sub-contractor will have its own project manager, most likely employed by the relevant sub-contractor, and it would be usual for the flying school project

owners to leave further WBS breakdown and detailed project planning for those sub-contracted elements to their relevant sub-project managers.

Figure 10.4 shows the project WBS as it would appear at the time of project authorization, when the project has been defined and the overall project manager has just been appointed.

CODING SYSTEMS

General

Every project task will need to be given a name or descriptive title, but such names must always be augmented by a specific code. Names usually describe the nature of the task (for example, dig hole, paint door, install and test new server and so on) but they do not usually indicate where the task lies with respect to the work breakdown or, indeed, within the physical breakdown of the finished project. Moreover, names are often abbreviated in schedules, so that 'test customer billing system' might be reduced to 'test cust bill' where column space is limited in a schedule or report. It is essential that every task be given some tag or code that identifies it uniquely and, at the same time, indicates its exact position in the WBS hierarchy.

A code may be a sequence of alphabetic characters, a set of numerical digits, or some mix of these two (an alpha-numeric code). Coding systems should be designed so that the maximum amount of information about each item is conveyed by the minimum possible number of characters.

The designer of a project management coding system must always bear in mind that it should not be treated in isolation from other management and engineering information systems in the same organization. There are many advantages to applying a common coding system over all company projects, and across other areas of the company's activities in addition to cost estimating, accounting and budgetary control.

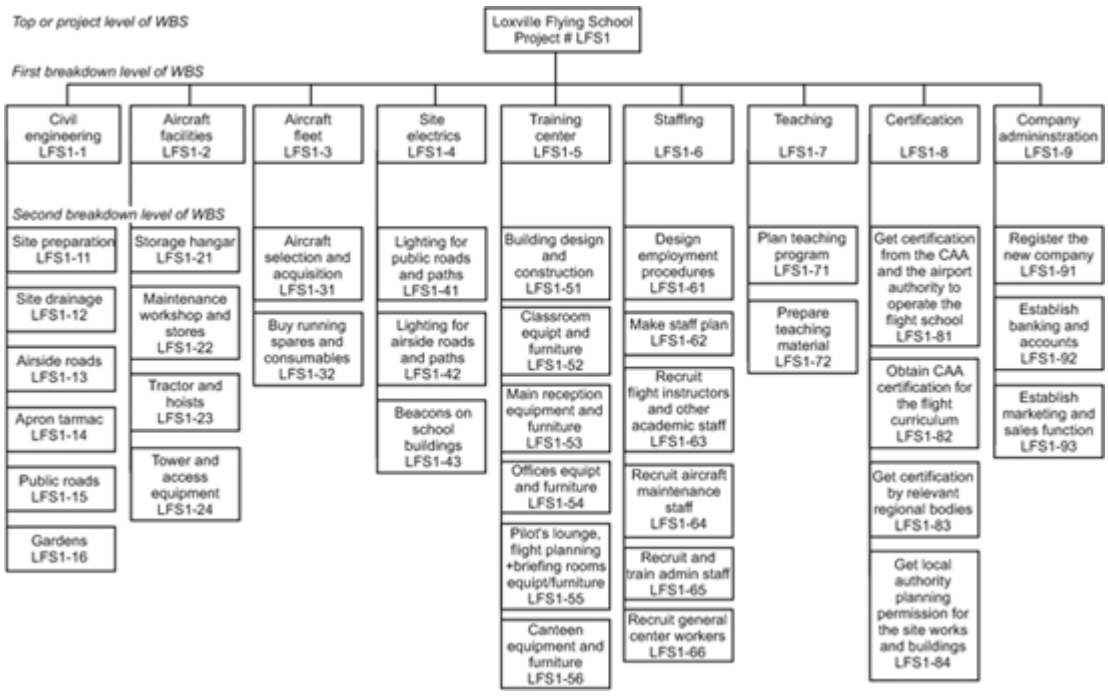

Top or project level of WBS
Loxville Flying School Project # LFS1
First breakdown level of WBS
Civil engineering LFS1-1
Aircraft facilities LFS1-2
Aircraft fleet LFS1-3
Site electrics LFS1-4
Training center LFS1-5
Staffing LFS1-6
Teaching LFS1-7
Certification LFS1-8
Company admininstration LFS1-9
Second breakdown level of WBS
Site preparation LFS1-11
Site drainage LFS1-12
Airside roads LFS1-13
Apron tarmac LFS1-14
Public roads LFS1-15
Gardens LFS1-16
Storage hangar LFS1-21
Maintenance workshop and stores LFS1-22
Tractor and hoists LFS1-23
Tower and access equipment LFS1-24
Aircraft selection and acquisition LFS1-31
Buy running spares and consumables LFS1-32
Lighting for public roads and paths LFS1-41
Lighting for airside roads and paths LFS1-42
Beacons on school buildings LFS1-43
Building design and construction LFS1-51
Classroom equipt and furniture LFS1-52
Main reception equipment and furniture LFS1-53
Offices equipt and furniture LFS1-54
Pilot's lounge, flight planning +briefing rooms equipt/furniture LFS1-55
Canteen equipment and furniture LFS1-56
Design employment procedures LFS1-61
Make staff plan LFS1-62
Recruit flight instructors and other academic staff LFS1-63
Recruit aircraft maintenance staff LFS1-64
Recruit and train admin staff LFS1-65
Recruit general center workers LFS1-66
Plan teaching program LFS1-71
Prepare teaching material LFS1-72
Get certification from the CAA and the airport authority to operate the flight school LFS1-81
Obtain CAA certification for the flight curriculum LFS1-82
Get certification by relevant regional bodies LFS1-83
Get local authority planning permission for the site works and buildings LFS1-84
Register the new company LFS1-91
Establish banking and accounts LFS1-92
Establish marketing and sales function LFS1-93

Figure 10.4 WBS for the Loxville Flying School Project

Functions of Code

A code is a shorthand and precise method for conveying essential data about an item. For project management purposes an item might be anything from the whole project to the smallest part of it, physical or abstract. It could be a component, a drawing, a job, a manufacturing operation, a piece of construction work, an engineering design activity, part of a computer program —anything, in fact, which is necessary for the project. One thing that practically all of these items have in common is that they are associated with cost. Each item (either by itself or grouped with others) has costs that must be estimated, budgeted, spent, measured, reported, assessed and (where appropriate and possible) recovered.

There are many reasons for allocating codes to items, rather than simply describing them in words. For example, codes can be designed to be precise and unambiguous. They also have the advantage, essential in computer database systems, of facilitating filing, analysis, editing and sorting for reporting and control.

The code for any WBS item will perform the first or both of the following functions:

1. A code acts as a name that *identifies* the item to which it refers. It must do this uniquely so that no two different items can share the same code.
2. A code can also (either by itself or by the addition of sub-codes) be arranged so that it categorizes, qualifies or in some other way *describes* the item to which it relates.

The best coding systems are those which manage to combine both these functions as simply as possible in numbers that can be used throughout a company's management information systems.

EXAMPLES OF CODING SYSTEMS

Coding systems are used widely by manufacturers to distinguish one of their products from another and those codes help customers in their choice of purchase. This practice is very common, for example, in the automobile industry and a person who buys a 3-series BMW knows that they will get a car with a smaller body than a 5- or 7-series vehicle. It is well known that aircraft manufacturers use codes that describe their products; for example Airbus model numbers are of the form A3nn, with examples being A300, A310 (<http,www.aerospaceweb.org/questions/q0276a.shtml>).

Codes for Boeing commercial airliners take the form 7n7-xxx, in which the outer two 7s of the first three digits proclaim that the aircraft is a commercial airliner. For example, a 747 is a four-engined large wide body aircraft, whilst a 767 is another commercial airliner, but with a twin-engined narrow body design. Boeing then add three more digits to identify each particular design variant. Thus a 767-300 is a particular variant of the Boeing 767. Boeing further developed this system so that two digits replace the final two zeros to identify a particular customer. Using this coding system, a Boeing 767-200 delivered to Air Canada would be coded 767-233 of the form 3nn, with examples being A300 and A310.

Coding the WBS for the Loxville flying school project

A simple but practicable coding system has been applied to the Loxville flying school project, the WBS for which was shown in Figure 10.4. At the highest level, the project entrepreneurs have decided to code this project LFS, to identify it as the Loxville Flying School project. But there might be

other projects carried out by this school in the future, so to name this as the first project in a possible series of projects the code has been extended to LFS1. Now the code tells us that this is the first Loxville Flying School project.

The first WBS level of breakdown identifies the major work packages of this project, each of which will be considered and managed as a sub-project. For example, all the civil engineering site works of earthmoving, leveling and drainage will be contained within a sub-project coded LFS1-1. The LFS1 element of this code clearly indicates that this is a sub-project of the main project LFS1, whilst the -1 suffix denotes the civil engineering sub-project.

Staying with the civil engineering works, we can see from Figure 10.4 that the next lower level of WBS identifies the biggest tasks within the civil engineering sub-project. For example, all airside road task codes will begin with the string LFS1-13, in which the last digit (3) makes this code specific for airside road design and construction tasks. If we had shown further levels of breakdown in Figure 10.4, we could imagine that LFS1-131 might be allocated to surveying and marking out the roads, LFS1-132 to excavating and leveling the road foundation beds, and so on.

Task LFS1-132, (excavating and leveling the beds for the airside roads) will itself contain tasks and this code, like most of the others, will break down into further WBS layers. For example, the contractor will need to hire plant to excavate and level the road foundations, and this acquisition of hire plant might be coded LFS1-1321. Every digit in every field in this code has relevance to the project hierarchy and tells all concerned what the task is and where it fits into the project WBS pattern. Figure 10.5 illustrates this concept, using the code LFS1-1321 as the example from the Loxville Flying School project.

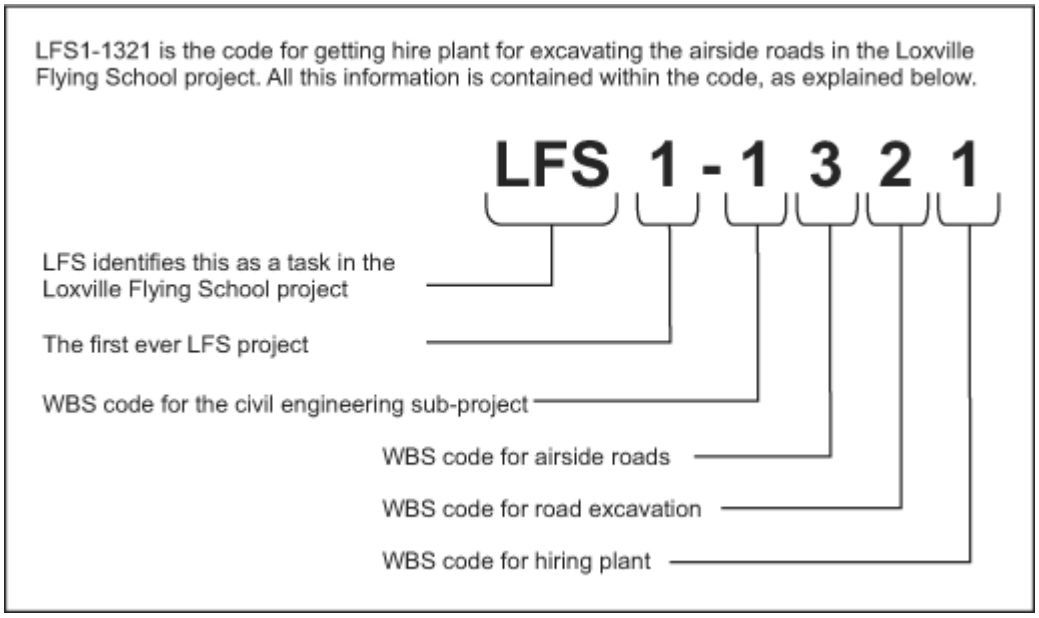

LFS1-1321 is the code for getting hire plant for excavating the airside roads in the Loxville Flying School project. All this information is contained within the code, as explained below.
LFS 1 - 1 3 2 1
LFS identifies this as a task in the Loxville Flying School project
The first ever LFS project
WBS code for the civil engineering sub-project
WBS code for airside roads
WBS code for road excavation
WBS code for hiring plant

Figure 10.5 A WBS code example chosen at random from the Loxville Flying School project

Later, additional code fields can be added to identify the type of cost or resource used on the task, and work-hours, consequential labor costs and the costs of materials could then be identified. Further breakdown codes are commonly used in projects to identify the part of the organization (company, department or manager) that will be primarily responsible for carrying out each task. This argument is developed and illustrated with more examples in Chapter 11.

A Coding System for an Aviation Radio Communication Equipment Project

Figures 10.6 and 10.7 are coding examples taken from a project to design and manufacture simple single channel airborne radio equipment for sale to light aircraft manufacturers or private owners to enable air to air or local ground to air radio communication. The equipment manufacturer has developed a coding system in which the codes follow a typical WBS pattern, as follows:

1. **Project identifier**—The project identification number for the breakdown shown in Figure 10.6 is 110-000. This number is sufficient to identify the project for all accounting, engineering and manufacturing purposes. Such project numbers are typically allocated from a register (which was

mentioned in Chapter 7). Some companies might call these project codes contract numbers or works order numbers instead. It is possible to design the project numbering method in a way that allows each number to signify certain key information about its project, in addition to acting as a simple identifier. Examples of this are also given in Figures 10.8 and 10.9.

2. **Item identifier**—Each number, provided it is unique within the system, is an unambiguous way of naming any item. It is easy, however, to transpose digits or make other errors when entering numbers on forms or keyboards and it is always wise to bracket a concise description with the number in records as a precaution against such mistakes. Thus in this radio communications project it is better to refer to an item as 'Transformer 110-221' in documents such as purchase requisitions rather than as just '110-221'.
3. **Relationship within the project**—Further examination of Figure 10.6 shows that the code numbers have been designed to correspond with the work breakdown (or family tree) hierarchy. Examples are given for components of the Transformer 110-221 and set out more clearly in Figure 10.7. The numbers denote that all numbers starting with the string 110 are used on Project 110-000 and, further that numbers starting 110-221 are used on Transformer 110-221.
4. **Operation identifier**—The task of winding the purpose-built transformer 110-221 might be given a related cost code, such as 110-221C, where the C suffix denotes the coil winding operation. A two-digit suffix is more likely to be used than a single letter, allowing greater scope for detailed breakdown into several individual operations.
5. **Identifiers for department, discipline or trade and labor grade**—A one- or two-digit sub-code is often incorporated to show which department is responsible for a particular task or cost item. More digits can be added to denote the trade or engineering discipline involved. Consider, for instance, the activity of designing Transformer 110-221. The cost code might be 110-221-153 with the three-digit sub-code 153 in this case showing that the engineering department (1) is responsible for the task, the engineering discipline is electrical (coded 5), and the last digit (3) indicates the standard cost grade of person (for example senior engineer, engineer or designer) normally expected to carry out the task of designing this transformer.

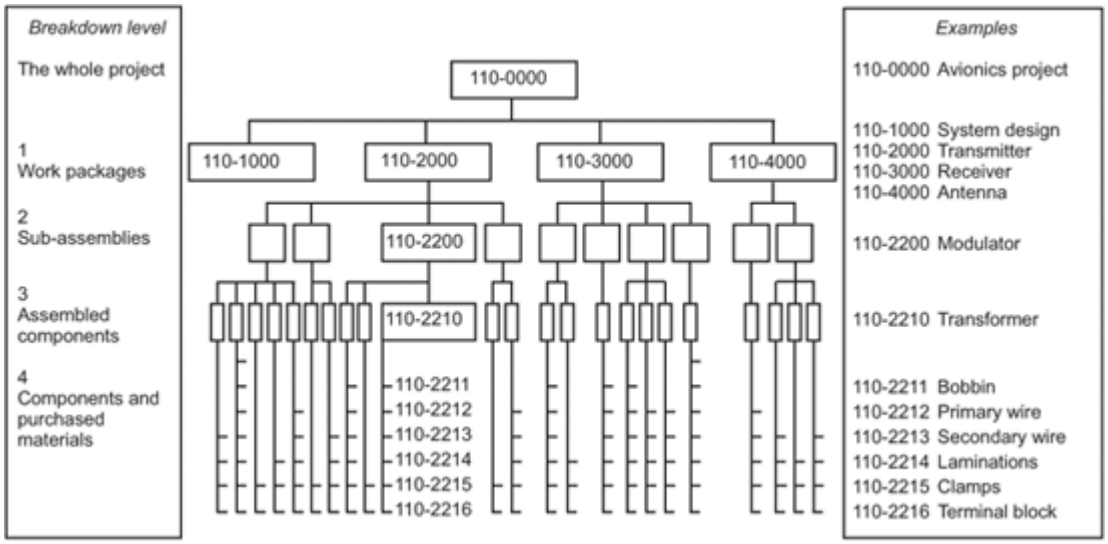


Figure 10.6 Part of the WBS and coding structure for a small aviation radio communications project

6. **Family identifier**—Many items to be considered for coding can be classified into families. Such families can extend across all projects in a company and can apply to huge capital projects or to the smallest engineering and manufacturing projects. The convenience of grouping items into families of items with common or similar characteristics is important for many comparative purposes. Family grouping and identification can be built into item codes using suitable digits as sub-codes.

A family might comprise, for example, all the different fluid pumps specified by an aircraft manufacturer, or all hydraulic actuators. Another type of family is encountered in machined objects that have similar shapes or other physical characteristics which need similar machining operations; an application of family coding which is vital to the manufacture of components in group technology cells.

Two Further Coding Examples used by Project Companies

A heavy engineering company This example comes from a heavy engineering company that designs and manufactures special purpose heavy machine tools. Some of this company's products are used in the aviation

industry for machining aircraft components. The system is very logical and works well over all the company's projects.

A contractor involved in large construction projects, such as a new airport development Our final example shows a notional but entirely practicable standard WBS and coding system for use by the main contractor for projects to develop and construct a new airport on a greenfield or brownfield site. We have based the overall concept here on our experience of an international mining company concerned with non-ferrous metals, gemstones and other minerals. Those mining projects included the multi-billion dollar development of new mines and their associated infrastructures (including road, rail and air terminals) and their well-proven project coding arrangements adapt very well for new airport development projects, as we have demonstrated in Figure 10.9.

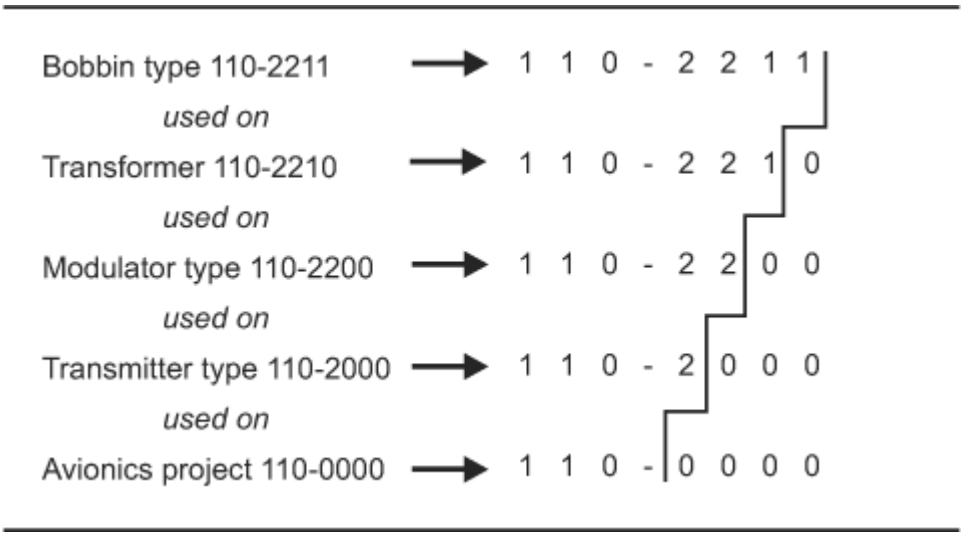

Bobbin type 110-2211 → 1 1 0 - 2 2 1 1
used on
Transformer 110-2210 → 1 1 0 - 2 2 1 0
used on
Modulator type 110-2200 → 1 1 0 - 2 2 0 0
used on
Transmitter type 110-2000 → 1 1 0 - 2 0 0 0
used on
Avionics project 110-0000 → 1 1 0 - 0 0 0 0

Figure 10.7 Detail from the radio communications project WBS

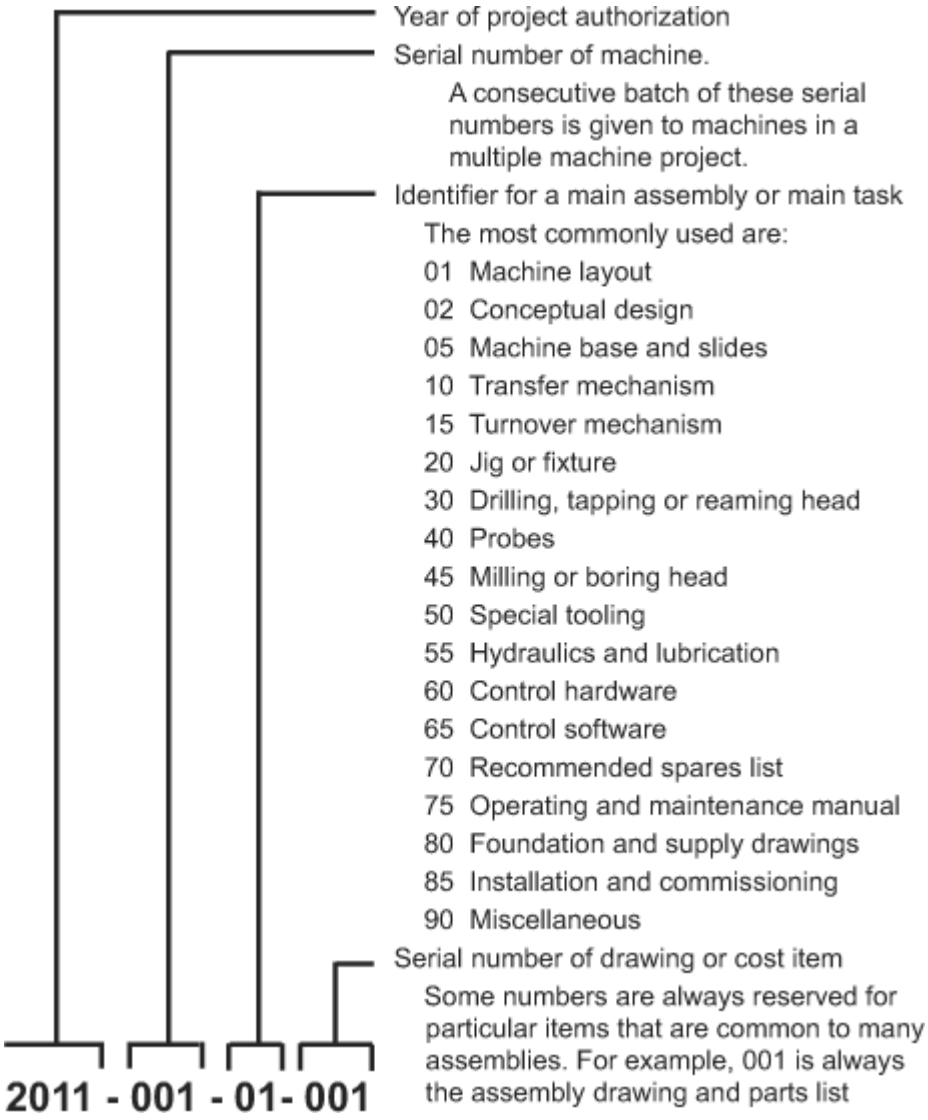

Year of project authorization
Serial number of machine.
A consecutive batch of these serial numbers is given to machines in a multiple machine project.
Identifier for a main assembly or main task
The most commonly used are:
01 Machine layout
02 Conceptual design
05 Machine base and slides
10 Transfer mechanism
15 Turnover mechanism
20 Jig or fixture
30 Drilling, tapping or reaming head
40 Probes
45 Milling or boring head
50 Special tooling
55 Hydraulics and lubrication
60 Control hardware
65 Control software
70 Recommended spares list
75 Operating and maintenance manual
80 Foundation and supply drawings
85 Installation and commissioning
90 Miscellaneous
Serial number of drawing or cost item
Some numbers are always reserved for particular items that are common to many assemblies. For example, 001 is always the assembly drawing and parts list
2011 - 001 - 01- 001

Figure 10.8 Codes used by a heavy engineering company

BENEFITS OF A LOGICAL CODING SYSTEM

The primary purposes of a coding system are usually to identify tasks (or project components) and to allocate cost estimates, cost budgets and actual costs, However, there are many benefits available to the company which is able to maintain a logical coding system in which all the codes and sub-codes have common significance throughout the company's management information systems. These benefits increase with time and the accrual of records, provided that the system is used consistently without unauthorized

adaptations or additions. The use of consistently operated codes in a relational database will bring order from potential chaos (Figure 10.10).

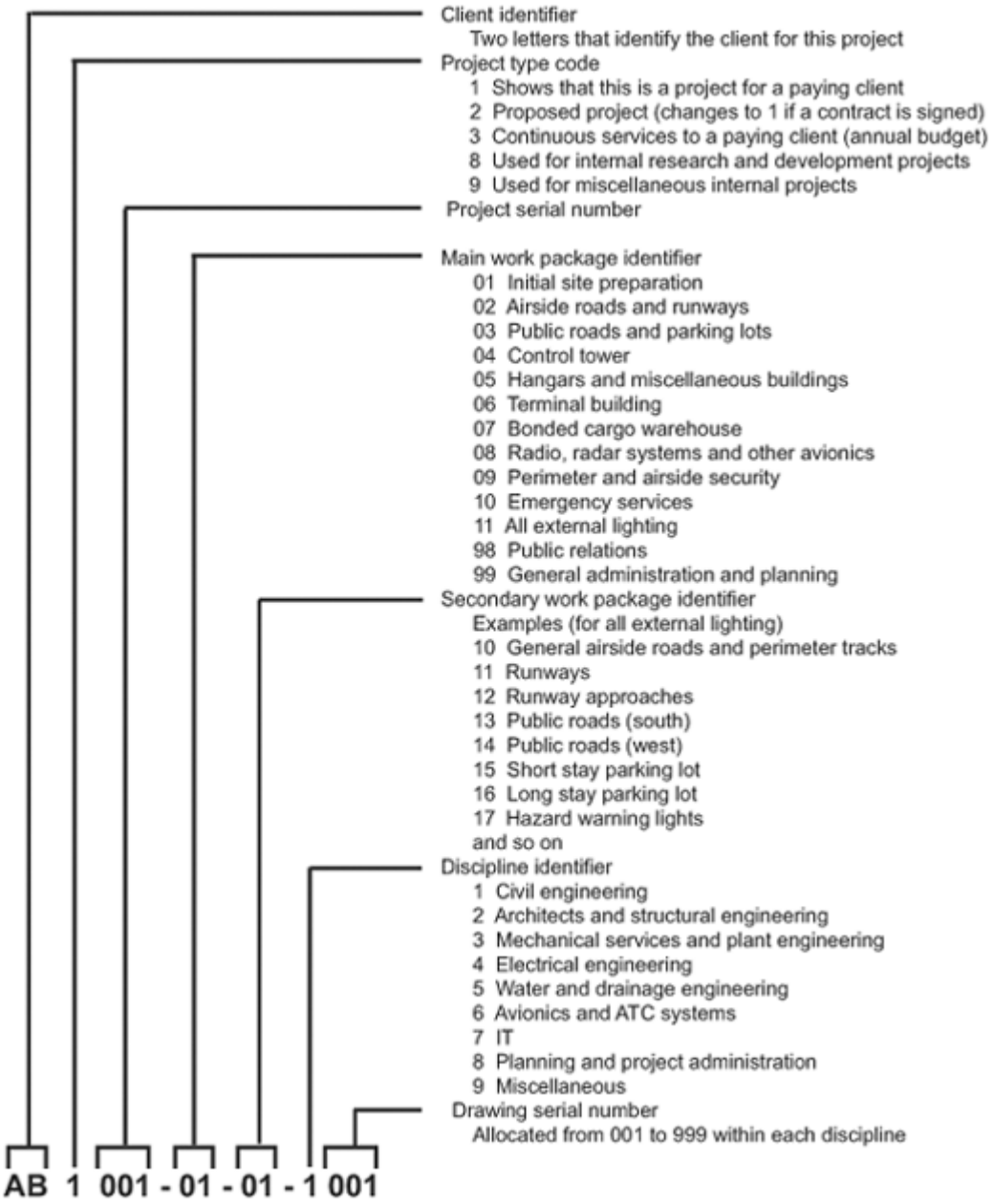

Client identifier
Two letters that identify the client for this project
Project type code
1 Shows that this is a project for a paying client
2 Proposed project (changes to 1 if a contract is signed)
3 Continuous services to a paying client (annual budget)
8 Used for internal research and development projects
9 Used for miscellaneous internal projects
Project serial number
Main work package identifier
01 Initial site preparation
02 Airside roads and runways
03 Public roads and parking lots
04 Control tower
05 Hangars and miscellaneous buildings
06 Terminal building
07 Bonded cargo warehouse
08 Radio, radar systems and other avionics
09 Perimeter and airside security
10 Emergency services
11 All external lighting
98 Public relations
99 General administration and planning
Secondary work package identifier
Examples (for all external lighting)
10 General airside roads and perimeter tracks
11 Runways
12 Runway approaches
13 Public roads (south)
14 Public roads (west)
15 Short stay parking lot
16 Long stay parking lot
17 Hazard warning lights
and so on
Discipline identifier
1 Civil engineering
2 Architects and structural engineering
3 Mechanical services and plant engineering
4 Electrical engineering
5 Water and drainage engineering
6 Avionics and ATC systems
7 IT
8 Planning and project administration
9 Miscellaneous
Drawing serial number
Allocated from 001 to 999 within each discipline
AB 1 001 - 01 - 01 - 1 001

Figure 10.9 Possible coding arrangement for a project to develop a new airport

The benefits depend on being able to retrieve and process the data effectively (using a suitable computer system). If a coding system is designed logically (taking account of both project hierarchical structure and families)

and if it is also well managed and never circumvented, some or all of the following benefits can be expected:

- Easy retrieval of items from records of past projects which correspond to or are similar to items expected in new projects, essential as a basis for making comparative cost estimates.
- Easy search and retrieval of design information (such as calculations and drawings) for processes, assemblies or components used on past projects which are relevant to a new project. This 'retained engineering' can save considerable engineering design work, time and costs if all or part of the previous design can be re-used or adapted. Not only does such design retrieval avoid the unnecessary costs of designing everything afresh, but it also allows the new project to incorporate designs that have already been proven or debugged, so that the scope for errors is reduced.
- Rapid identification of purchase requisitions and specifications from previous projects for equipment which corresponds to new equipment requirements. One application of this is to speed the preparation of new purchase specifications, particularly when much or all of the previous text can be used again.
- Grouping of components into families according to their basic shapes and sizes, especially for manufacturing operations where the plant is arranged in group technology cells.
- If it is possible to use a common system, cost estimates, budgets, recorded costs, drawing schedules, many other documents and tasks on the project plan can all be related in a database for project administration, management reports and control.
- The ability to carry out statistical analyses on cost records and other documents from past projects is invaluable for many reasons.

The consistent use of a logical coding system in an engineering company from our past experience produced many benefits. The following examples illustrate only two of the many possibilities for exploiting properly coded records:

- The averaging of recorded costs for commonly recurring work packages in a range of categories from many past projects enabled the preparation

of project estimating tables (expressed in labor-hours and updated materials costs). These tables proved very useful for planning and resource scheduling new projects and for making global checks on detailed estimates for new project proposals.

- Analysis in detail of past shipping records made it possible to compile a table that listed all the main components commonly produced in the company's very heavy engineering projects. For each item it was possible to forecast the most likely average and the maximum weight of each part of the project after it had been broken down into parts of 20 tonnes or less for shipping. Cost estimates were added with the help of a shipping company. The result was given to the materials control manager as a 'ready-reckoner'. With occasional updating, this table was used successfully for estimating future project shipping weights and costs to all parts of the world.

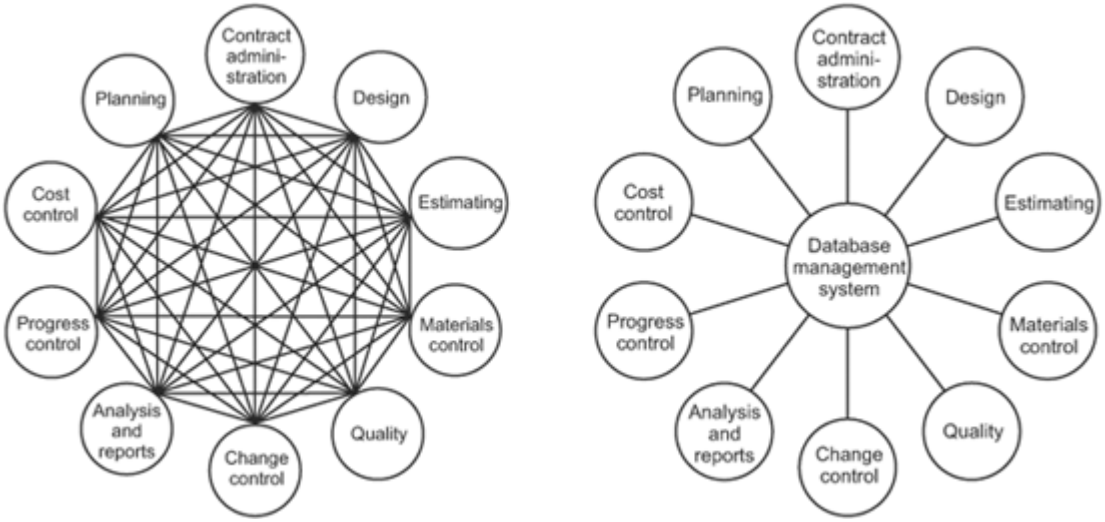


Figure 10.10 Coded data in a database brings order from chaos

CHOOSING A CODING SYSTEM

Once a coding system has become well established it is difficult and unwise to make any fundamental change. Any comprehensive system has, therefore, to be designed with a great deal of care, so that it will serve the organization well into the future. Suppose that a company has been operating for many years with a comprehensive arrangement of codes that are recognized by all its management information systems. Suppose, further, that this arrangement

of codes is common to many applications and procedures. As an example, the number for the drawing of a manufactured component would also be used as (or would be a recognizable constituent of) related manufacturing job numbers, job cost records and the stock and part number of the component itself. If this company were to make a change to its numbering system, so that numbers which previously had one meaning would denote something entirely different in the future, all or some of the following problems would arise:

- drawings filed under two different systems;
- similar inconvenience caused to long-standing customers who maintain their own files of project drawings;
- no easy way of identifying similar previous jobs for the purpose of comparative cost estimating;
- difficulty in retrieving earlier designs. The benefit of re-using retained engineering from past work to reduce future design effort might be lost;
- staff must live with two different systems instead of one universal set of numbers;
- problems for storekeepers and stock controllers, with more than one part numbering method—parts common to earlier projects may have to be renumbered for newer projects, so that there is a possibility of having identical common parts stored in two places with different part numbers;
- mayhem created in any attempt to use a relational database that relies on code numbering.

The Need for Simplicity

This is the place to insert another word of warning. It is tempting to be too ambitious and try to make numbers include too much information. The result can be codes that contain 14, 15 or more characters. It is easy to fall into such a trap, especially when the system is designed by a committee, each of whose members contributes his or her own idea of what the numbers might be expected to denote. Beware of phrases such as ‘Wouldn’t it be nice if…’.

The designer of a system that depends on exceptionally long codes may feel very proud of their system’s capability. Computer systems are well able to accept and process huge numbers, but please remember the human element —the ‘people interface’. People will have to work with these numbers,

entering them in written or electronic records. We remember an attempt to introduce a very complex coding system on a mine development project in a remote area of Australia. The system designer was a highly qualified and well-respected member of the London head office management staff. Supervisors, professional people and artisans at the mine were all expected to read and write 18-digit job codes on documents without making mistakes while exposed to unpleasant and hazardous conditions both above and below ground. The people at the mine never even attempted to use the codes. Even if they had used them, the depth of information that the codes contained was far in excess of that needed for project management. Simple codes use less effort and result in fewer errors. Remember the sensible slogan KISS: **K**eep **i**t **S**imple, **S**tupid.

WHAT HAPPENS WHEN THE CUSTOMER SAYS 'YOU SHALL USE MY CODING SYSTEM!'?

Not infrequently, an irritating problem arises when customers insist that their own numbering system is used, rather than the project contractor's own long-established and proven arrangement. This happens, for example, when a project owner is to be presented with a complete set of project drawings as part of the contract and wants to be able to file these along with all the other drawings in the owner's head office system. This, unfortunately, is a case where 'the customer is always right'.

This problem of having to use customers' codes is not always restricted to drawings. In some projects it can apply to equipment numbers or part numbers. It also occurs, and is a great nuisance, in the cost codes used for work packages or large purchases for major projects. The customer and contractor sometimes work together to plan, authorize and arrange the release of funds (either from the customer's own resources or from an external financing organization). In such cases the customer might insist that all estimates, budgets and subsequent cost reports for the project are broken down against the customer's own capital appropriation or other cost codes.

Three Options

There are three possible options when the customer asks the contractor to use a 'foreign' coding system.

Option 1: Say 'No!' to the customer The person who adopts this course is either courageous or foolhardy. It might even be impossible under the terms of contract. In any case, it would be a short cut to achieving bad customer relations or losing the customer altogether.

Option 2: Change over completely to the customer's system With this option, the contractor calls the project a 'special case', abandons the in-house system, asks the customer for a set of their own procedures, and uses those for the project. This option cannot be recommended for the following reasons:

- the information management benefits of the in-house system would be lost for all data for the project;
- it will soon be discovered that every project is a 'special case'. The contractor might soon have to deal with as many coding systems as there are customers.

Option 3: Use both systems simultaneously This option, the sensible compromise course, offers the only proper solution. Every drawing and other affected item must be numbered twice, once for each system.

Everything must, of course, be diligently cross-referenced between the two systems. This is tedious, time consuming and means that staff have to learn more than one system. Some time ago it would have caused enough extra work to provide a weak argument for trying to obtain extra reimbursement from the customer. Fortunately, computer systems greatly reduce the effort needed for cross-referencing, sorting and retrieving data numbered under duplicate systems.

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11
Relating the Project Dimensions of Work, Organization and Cost

A typical project has many dimensions, such as people, time, organization, work, cost, benefits, cash flow, stakeholders and many others. All these can interact with each other and affect (or be affected by) every project task and all have to relate to other company systems such as the management information system. The number of decisions facing the aviation project manager when dealing with this complexity is so great that everything has to be planned and structured piece by piece, one dimension at a time, in a predetermined and logical fashion. The project manager who fails to appreciate that will produce chaos and a failed project.

DIMENSIONS OF A TYPICAL AVIATION PROJECT

Time as a Very Special Case

The average person asked to name the most important project dimensions would undoubtedly pick cost and time. People might also be chosen as a key dimension, because no project can be successful without the willing performance of its sponsors and workers. But time has to be singled out as a very special case, because it is the one dimension over which we mere mortals have no control whatsoever. As poets and writers have observed throughout the centuries, time moves relentlessly onward and, once gone, each moment has gone for ever.

> The moving finger writes; and having writ,
>
> Moves on: nor all thy piety nor wit,
>
> Shall lure it back to cancel half a line,

Nor all thy tears wash out a word of it.

Omar Khayyam (c.1048-1122) transl. Edward Fitzgerald

So we can only plan for the dimension of time and react to its progress and passing. As a special case, we devote several following chapters to planning and controlling projects against time, but we cannot change time itself. All the other project dimensions are different, because the project manager has some power or influence that can control or alter them. Thus the important subjects of time, planning and the associated scheduling of resources require special treatment and their appropriate methods are dealt with in later chapters. Here in this chapter we focus our attention on how three other important dimensions must be regarded and linked. These dimensions are work, organization and cost.

Three important Project Dimensions for the Aviation Project Manager to Consider

In addition to time, there are three particular project dimensions that the project manager must be able to comprehend and relate to each other. These dimensions are:

- **The work dimension**—the understanding of which begins with project definition, then proceeds through listing as many tasks as can be imagined, and is finally defined by formal arrangement in the WBS (described in Chapter 10).
- **The organization dimension**—which means how different people, companies, divisions, functional departments, work groups, sub-contractors, major suppliers, funding banks and others are placed in the organization structure and how they communicate with each other. Chapter 8 (and to a smaller extent Chapter 9) described some of these aspects.
- **The cost dimension,** which means the estimated, budgeted and actual costs of all the work. When dealing with cost we have to consider individual tasks, the costs incurred by people and departments, and (collectively) the entire project. This important dimension of cost was introduced in Chapter 5 and also features in several later chapters along with the closely associated dimension of cash flow.

Every project task has its own relationship with the WBS, cost breakdown structure (CBS) and organization breakdown structure (OBS). The picture for any big project is extremely complex and difficult for even the expert to understand because it contains a vast amount of data that is dynamic and changes with time and progress. Further complications are created when changes are made to the project specification or scope. Some idea of this complexity is conveyed in Figure 11.1.

MANAGING THE INCOMPREHENSIBLE AND CREATING ORDER OUT OF CHAOS

Fortunately the human brain is not required to visualize every small detail of the complex and dynamic dimensional pattern for any modern project. Instead, we can access computer systems that, because they are built on relational databases, are capable of processing any combination of data that we need and reporting the results in almost any convenient format of our choice. All good project management software is well suited to that Herculean task. It is dynamic (and can react rapidly to changes) provided that we supply the appropriate data.

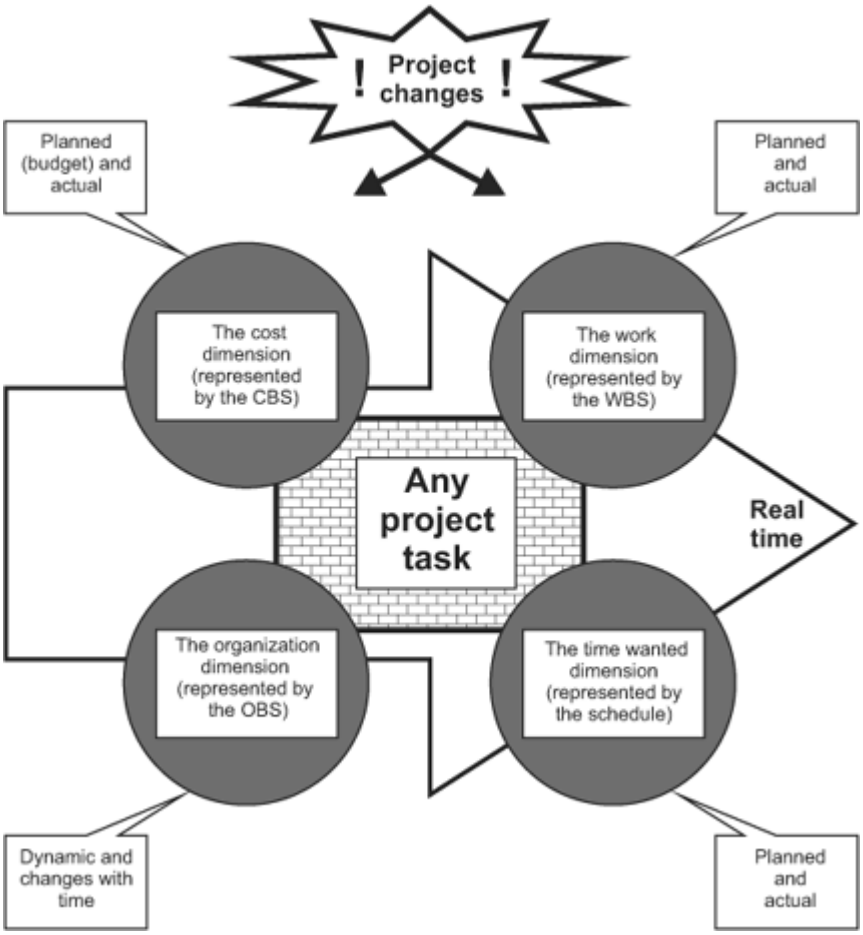

! Project changes !
Planned (budget) and actual
Planned and actual
The cost dimension (represented by the CBS)
The work dimension (represented by the WBS)
Any project task
Real time
The organization dimension (represented by the OBS)
The time wanted dimension (represented by the schedule)
Dynamic and changes with time
Planned and actual

Figure 11.1 Some of the many project dimensions that can interact with every project task

All this depends on the project manager having a full understanding of the project and its breakdown structures (particularly the WBS and OBS). It depends also on the use of rational coding systems that can attach a hierarchical code to every task in the WBS and to every part of the OBS. Data without codes are hidden and useless data.

Most of what follows in this chapter explains the architecture of the work, organization and CBS and the relationship between them. Even in a small project there will be a wide variation of permutations and combinations possible from all the project data. Further, the data will be changing with time and progress. However, the project manager needs only to understand and work within the underlying concepts and can leave the formidable task of extracting and reporting management information to the computer and its specialist project management software.

None of the project dimensions exists by itself, and all are interrelated in various ways, both within the project and with the company's general

management and accounting procedures. They overlay each other or are interlaced in many complex ways. The project manager must be able to see across and into these complex patterns in detail and make sense of them if the project is to be managed successfully. This might seem to be an impossible task for the average human mind and, indeed, these dimensional relationships are not easy to describe in words and pictures. Very few project management writers actually try. Fortunately, however, all this complexity can be reduced to sensible and manageable proportions by taking the following relatively straightforward steps:

1. prepare a WBS for the project and code it hierarchically;
2. prepare an OBS and code that hierarchically too;
3. allocate the relevant WBS and OBS codes to every task;
4. derive cost codes by combining the WBS or OBS codes as required (described later in this chapter);
5. using competent project management software, arrange for a computer to process, sort, filter and report data according to the WBS and OBS codes so that managers throughout the organization get schedule, progress and cost data that are specific to their own responsibilities (on a need-to-know basis).

Chapter 12 described the first of the above steps (WBS preparation), so now it is time to consider the OBS.

INTRODUCING THE PROJECT OBS

Strictly speaking, the OBS of a project is concerned with the internal organization of that project and is not necessarily identical with all the organizational elements of the parent company, as they might be depicted in its organigram. The OBS is always set out and coded in a hierarchy similar to the WBS.

However, the OBS will undoubtedly conform to part of the overlaying company organization and the company's organigram is usually the starting point for designing a project's OBS. In many companies the OBS of every project will correspond exactly to a part of the company's general organization (but will exclude departments that are never involved in project work). It would be a very stupid project manager who did not use OBS

codes that were either identical to, or could easily be related to the organizational codes used in the company's management information system.

The picture changes for projects that are conducted by two or more companies working in partnership, even when that partnership is informal and not cemented into a joint venture or consortium arrangement by contract. In all multi-company projects, the project OBS transcends the organization chart of any single company. Thus the size and pattern, and the number of levels in a project OBS will depend very much on the size of the project and the number and type of different organizational elements involved.

Consider, first, the very common case of a small project carried out by a single company. Assume that (apart from minor sub-contractors) the parent company contains all the departments and groups necessary for the project. In such projects the company is represented in the OBS by a single element placed right at the summit of the hierarchy. Level 2 of the OBS will then represent the breakdown of the project into its principal organizational elements, which will often be company departments. This process is repeated until the smallest organizational elements are identified at the lowest level of the OBS. This lowest level usually comprises the smallest functional working groups.

When several companies work together on one project (which is very common in aircraft development and other big aviation projects), the element at the top of the OBS hierarchy will represent the entire organization, in which all the companies involved are included and combined. Level 2 of the OBS will then separate this conglomerate into the separate companies, with one OBS element allocated to each company. Then the OBS will continue downwards into its lower levels, breaking each company separately into its smaller organizational elements.

Figure 11.2 shows how the various OBS levels might be arranged for different project sizes. There is no norm, so there will be many variations on how these breakdown levels are chosen and named by different organizations.

A PROJECT CASE EXAMPLE

We now introduce a case example to show how the WBS, OBS and (eventually) the CBS for a fairly small project would be arranged and related

with each other. We have kept this example simple so that the breakdowns can be shown clearly in these pages but, once these principles are understood, scaling up to larger projects is straightforward.

Project Description

This case example project is to be conducted by a (fictional) company called Airpress Test Inc (ATI), which specializes in the design and manufacture of pressure testing equipment for the aviation industry. The project requirement is for the design and manufacture of a machine for cyclical pressure fatigue testing of aviation components, such as radomes, fuel tanks, parts of cabin and fuselage assemblies and so on.

Each of these different applications will need its own test rig but those will be designed and built by the aircraft manufacturers who buy the test units. Our project is concerned with the design and manufacture of the basic trolley mounted pressure cycle test machine.

OBS level	*Small-size project organization*	*Medium-size project organization*	*Large single project organization*	*Program or multi-project organization*
Level 1	The entire project	The entire project	The entire project	The entire program
Level 2	Departments	Divisions	Companies	Individual projects
Level 3	Groups	Departments	Divisions	Companies
Level 4	Not used	Groups	Departments	Divisions
Level 5	Not used	Not used	Groups	Departments
Level 6	Not used	Not used	Not used	Groups

Figure 11.2 Some of the many possible arrangements for deciding OBS levels

The product will be housed in a rugged case containing components such as electrically driven air pumps (vacuum and pressure), tubing, valves, switches, electronics and instrumentation (including a timer and counter). The unit will be capable of carrying out either pressure or vacuum testing on aircraft components or test rigs with a maximum internal volume of 1000 cubic feet. The minimum pressure level can be set by the test operator to represent an altitude equivalent to 60 000 feet. At the pressurization peak, the machine can produce a maximum pressure variable up to 4 bar if required.

The time for a complete pressure change cycle can be varied by the operator to a maximum number of ten cycles per minute for the largest aircraft components or structures. Maximum and minimum pressures can be preset from a control panel, and airflow rates are adjustable to achieve the required cycle times. The machine can be programmed either to run a test for a given time, or for a given number of complete pressure cycles. Thus this machine will be able to carry out accelerated life tests in an attempt to discover faults in design, manufacturing or materials that could cause pressure fatigue cracks to develop in aircraft components or structures during service.

WBS for the ATI Pressure Test Units Project

Most of the WBS for the ATI project is shown in Figure 11.3. As this is the 99th project undertaken by the ATI company, the project has been coded as 099. It can be seen in Figure 11.3 that every element of the WBS has been coded, and that all codes obey the logical hierarchical rule. Thus, taking a random example from the bottom (fifth) level:

the printed circuit board	099-1311
is required for the circuit board sub-assembly	099-131
which is fitted to the control panel sub-assembly	099-13
that is used on the main assembly	099-1
for the project	099.

OBS for the ATI Pressure Test Units Project

The organization breakdown for this project is identical to part of the organization of the ATI company, but it excludes the administration departments (such as HRM) that are always treated as overheads and which cannot accrue any costs directly attributable to the project. For the same

reason, senior management are excluded. On the other hand, we have deliberately kept this example simple and no doubt in practice a few other groups would need to be included. For example, there might be a pneumatic engineering group in the design department and a production engineering group in the manufacturing department.

This OBS is shown in Figure 11.4. Again each element of the breakdown has been given a code according to a logical hierarchy. Alphabetic codes have been used here to help identify the different departments, so that D has been allocated to the design department, P to the procurement department and M to the manufacturing department. It is always good practice to make codes 'user-friendly' in this way because it makes the codes easier to recognize and helps to avoid errors.

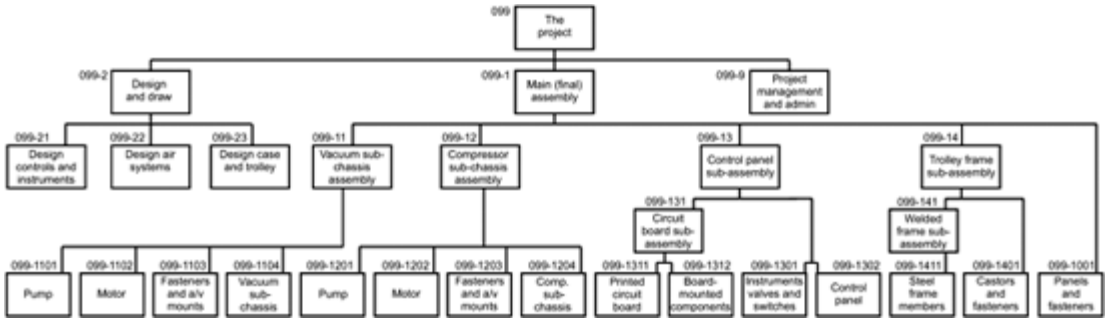


Figure 11.3 Part of the 5-level WBS for the ATI pressure test units project

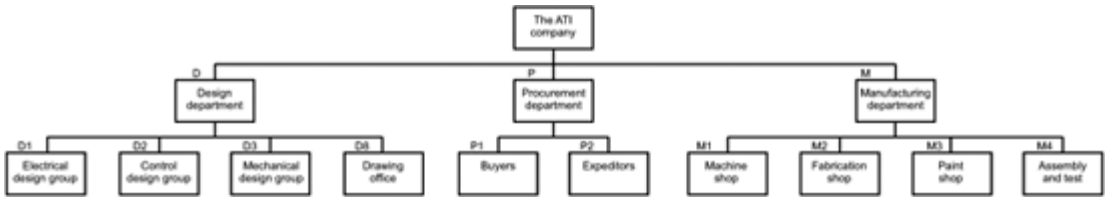


Figure 11.4 3-level OBS for the ATI pressure test units project (and all other projects carried out by the ATI company)

Three levels of breakdown were sufficient for this small project, but in a larger project it will clearly be necessary to have one or more further levels of breakdown, down to the individual functional groups, as we have already shown in shown in Figure 11.2.

RELATIONSHIP BETWEEN THE PROJECT WBS AND OBS

The ATI pressure test units project's WBS and OBS have been brought together as a matrix chart in Figure 11.5. At each intersection of the matrix there is a possible cost account that relates the work required from the WBS with the organizational group that will carry out the work and incur the cost.

Although the WBS and the OBS shown here are both somewhat simplified, it is apparent that even for this tiny project this is a complex pattern in which it is hardly possible to show or even imagine every possible cost account.

If this were a very large project, a diagram showing every possible cost account might need a sheet of paper as large as a football pitch. However, here are two items of good news:

1. Even though Figure 11.5 is greatly simplified, it is adequate for demonstrating the principles of the WBS/OBS/cost account relationships.
2. In practice project managers need only produce the WBS and OBS separately, and will never have to draw the complex relationship diagram. As we have already described, if the coding systems are logically designed, the relational database in the computer will take care of the complexity. So that enormous sheet of paper will never be needed.

Generating Cost Accounts from the WBS and OBS

Before describing Figure 11.5 in more detail, we must admit that production engineers and similar experts might find cause to disagree with the way in which we have chosen to break this project down for design and manufacture. There is usually more than one way of arranging such structures and we do not claim to show the best solution. However, our breakdowns are just perfect for demonstrating the method and the concepts.

To understand in greater detail how the WBS and OBS relate, look for instance at task 099-11, which is in the third level of the WBS in the upper portion of the diagram. This task covers all work relating to the design and provision of the steel vacuum sub-chassis (on which will be mounted a motor, vacuum pump and small storage tank, some wiring and electrical connectors).

Running the eye vertically downwards from this task reveals that it interfaces with a number of elements from the OBS. For example, the electrical design group (coded D1) will specify the wiring and connectors within this sub-chassis. All the costs attributable to this job within the electrical design department will be allocated to the cost account 099-11D1.

When the drawing office produces the final drawings for this vacuum sub-assembly, they will charge their time to cost account 099-11D8. In an ideal drawing system, the drawing serial numbers will also be coded to correspond in some way with these WBS and OBS codes.

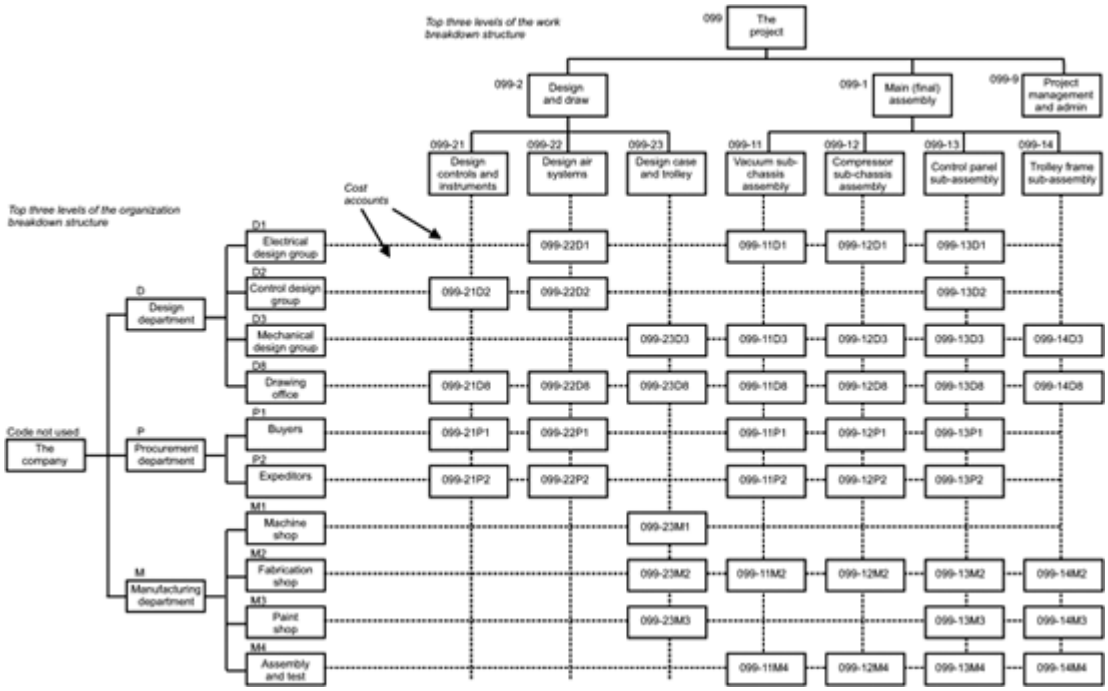


Figure 11.5 Formation of some higher-level cost accounts for the ATI pressure test units project

Clearly not every task will involve every department, and that is apparent in Figure 11.5 by the number of intersections where no cost accounts exist.

We stress again that there is no need in practice to produce a drawing such as this, because provided the WBS and OBS are suitably coded the computer will create the relationships and assign the data from its database.

Now we have a system for allocating the costs of time and materials not only to each task, but also to the group or department that does the work. All of these results will depend on having systems for collecting the actual costs as they are incurred, and that subject is dealt with in Chapter 24. Those cost

collection systems will need yet more codes (not discussed here) which include the following:

- **Staff codes**—that identify individual people within HRM and payroll records.
- **Standard cost codes**—codes that identify the hourly cost rates attributable to different grades of staff in the labor cost structure.

With the OBS, WBS and all these coding systems in place, we can now contemplate one further related system, which is the cost breakdown structure (CBS).

INTRODUCING THE CBS

So far it is apparent that, using a combination of the WBS, OBS and the resulting cost accounts, it is possible for a computer to compile cost reports that break costs down into tasks and the organizational elements involved in carrying out those tasks. However, project managers, cost engineers and some senior managers will be interested in yet another dimension, which is how the project costs can be grouped ('rolled up') by categories such as total labor, total bought-out materials and total expenses. Putting this argument in a different way, so far (as demonstrated in Figure 11.5) we have only attempted to interface the OBS and the WBS at a single combination of levels. We chose to introduce the dimension of the CBS by interfacing the third level of the WBS with the third level of the OBS.

This combination at third levels is useful for the project manager because it enables the computer to collect and report costs for every level-3 task from the WBS and to report the departmental expenditure for every level-3 OBS element on those tasks. This gives us the beginning of another kind of matrix breakdown, which is the CBS.

Managers at different levels in an organization will be interested in known costs collected from levels appropriate to their seniority. Thus the company president will be interested in project costs at company level in the OBS and at project level in the WBS. More junior managers will ask for more detailed cost reports that drill down into their part of the organization and the work for which they are responsible.

All these cost account elements are obtainable for the ATI pressure test units project from the WBS and OBS patterns shown in Figure 11.5. For example, the total costs of design on this project would be available from the computer against the cost code 099D. The total costs for the company are rolled up by the computer at the top of the WBS, against the code 099. Similarly, code 099M should represent the total cost of manufacture for this project.

A diagrammatic representation of this would be difficult to draw and impossible for anyone to understand, but we can show the concept in a stylized way for a typical small project. We have done that in Figure 11.6. This represents in a general way the interaction of the OBS and WBS at different levels to produce cost accounts for tasks and organizational elements at the various levels which different managers and supervisors will need to help them monitor and control project costs.

Remember that this seemingly extremely complex set of permutations and combinations is reduced to a relatively easy operation once the WBS and OBS have been designed and coded for the computer's database.

Although this is not the most exciting aspect of project management, and is somewhat difficult to explain (and even more difficult to comprehend), a good, logically coded WBS and OBS set the scene and provide essential foundations for subsequent project cost management.

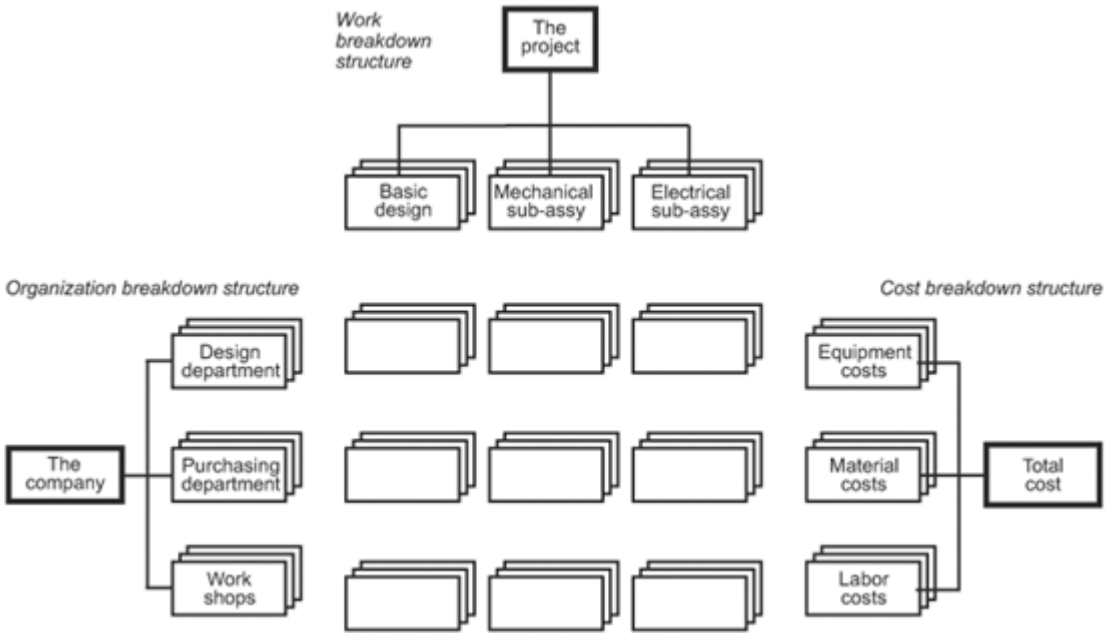


Figure 11.6 Three-dimensional WBS-OBS-CBS structure for a single-company project

CASE EXAMPLE: CASH CRISIS AT JET-U-THERE

This case example demonstrates how an international airline might embark on a project to refocus its business activities to improve financial performance and competitive edge. The project is centered on an imaginary company called Jet-U-There, which operates a network of services out of several airports in US cities to worldwide destinations. Business and private passengers are catered for, as well as some freight.

The Project Background

At the time of this project Jet-U-There had been in business for about five years, during which time it had experienced rapid growth and built up a good reputation for customer service and reliability. However, not all routes were profitable and this, together with some administrative and organizational weaknesses, has recently produced some disappointing financial results. Cash flow deficiencies had become sufficiently serious to threaten the future of the business. Clearly something had to be done, and done quickly. The senior management at Jet-U-There realized that fundamental changes would be required and they also knew that such changes would be best approached and implemented by setting up a management change type of project.

Although urgent action was needed, the company was anxious to avoid ill-considered panic measures. The financial vice president reported that the firm had about six months in which to plan and implement changes if it was to prevent risk of insolvency or exposure to hostile bids from competitors. So it was decided to conduct an internal study to decide the most appropriate project strategy. As we outlined in Chapter 4, a SWOT analysis is a good place to begin when formulating business strategy and that is exactly what Jet-U-There did.

SWOT Analysis Preceding the Jet-U-There Project

To avoid creating unnecessary rumors among staff, the SWOT meeting was held off site in a hotel conference room and attendance was restricted to senior executives. It was clear that downsizing in one or more departments

would be an inevitable result of the project, so preliminary studies had to be carried out with some secrecy to avoid creating panic among the workforce. The top managers had to have their strategy in place before making any announcement to the workforce. Such rumors and uncertainty about the future always cause valued employees to lose their motivation. They might interface badly with customers or resign prematurely. After weeding out unhelpful or inappropriate suggestions, the following results emerged from the SWOT analysis meeting.

Strengths

- Loyal staff, with a good working atmosphere. It was noted particularly that their bonhomie extended beyond business hours into social and sporting activities.
- Contented staff, without any distracting issues, who tended to deal well with customers.
- Loyal customer base. For example, 95 per cent of passengers who completed customer satisfaction questionnaires reported that they would fly Jet-U-There again. Roughly the same proportion said that they would recommend the airline to their friends. These satisfaction levels related to flight service, and were slightly offset by some dissatisfaction in a few cases concerned with difficulties in making flight reservations.
- Good credit rating. The company had a good relationship with its suppliers and service providers and is well known for paying bills in full and on time.
- Modern aircraft fleet. All aircraft were purchased new and none was over five years old. All planes were suitable for the services where they operated.
- Good MRO arrangements. All planes received competent maintenance, repair and overhaul service through reliable sub-contractors at key destinations.
- One department that performed consistently well was an outsourced customer service facility called Callex, based in New Delhi, India. This was a call center that dealt principally with standard tariff inquiries and reservations made online by private customers.
- Although the company's IT systems had become somewhat outdated and overloaded, one great strength was in the support provided by the IT and

telecoms consultants Densys Inc. This consultant operated a 24-hour hotline and could provide technicians immediately from a base only five minutes drive away from Jet-U-There's head office. For this reason, good IT reliability was regarded as a current strength.

Weaknesses

- The biggest weakness and money loser was identified as a less than perfect network. This included some routes that were unprofitable for a number of reasons, including flight delays and cancellations caused by unpredictable regional weather conditions and, in one case, political unrest in the destination country.
- Some seat pricing was subject to a complex tariff that even headquarters customer services staff found difficult to understand. Whilst the New Delhi call center dealt very well with booking requests for standard tariff seats, private customers wishing to take advantage of promotional offers or seasonal discounts were usually referred back to head office for processing by Jet-U-There customer services staff. The tariff complexities were such that they occasionally mistakenly sold seats at wrong prices.
- One serious weakness was identified as the degree of uncertainty associated with group bookings made in advance by tour operators. Operators would reserve capacity months ahead of requirement by booking blocks of seats. Unfortunately these booking levels were often optimistic, because the operators were apprehensive about not being able to satisfy all their customers. Some safeguards were in place, but these were not always effective. When the busiest holiday dates arrived, not all reservations were taken up, leaving planes flying with empty seats. Currently these group bookings were handled by the same head office customer services staff who handled private bookings.
- Associated with the above item, the standard terms of contract offered to group tour operators were clearly too lenient and provided for inadequate compensation to Jet-U-There when tour operators made excessively large block reservations.

Opportunities

- It was known that new routes could be opened up that would potentially be at least as profitable as the best performing current services.

- The call center in New Delhi had considerable spare capacity and had been toting for an increased share of the customer services action. Their operating costs were substantially lower than those at the Jet-U-There home office for comparable work. Switching some more customer services action to Callex would clearly make sense and reduce costs.
- There appeared to be an opening for running more educational flights for student and teacher groups. The company already operated routes to places with ancient monuments and other features or educational value. This appeared to have been a missed opportunity that might benefit from a well-targeted marketing campaign. However, this would add to the number of group advance reservations and would need careful market research and business forecasts if the risk of more empty seats were to be avoided.

Threats

- The most immediate threat was to cash flow, with deteriorating income competing with rising wages in the home offices. This would lead to serious losses within six months if nothing were done to reverse the conditions. Short-term losses could be met from capital reserves but the company would run into unsustainable debt within about six months if corrective action was not taken.
- At least two competitors flew to the same destinations as Jet-U-There. Although their brand images and customer satisfaction ratings were lower than those currently enjoyed by Jet-U-There, there was no guarantee that this would continue. Jet-U-There would lose its competitive edge if it did not arrest the weaknesses in its seat reservations service.
- Company ownership would be at risk from low-priced hostile bids once the company's poor cash flow performance became known.

A Rescue Strategy Based on Four Management Change Projects

Jet-U-There's president agreed to implement a program of four new projects to improve company performance. These projects were as follows:

1. Review the service network, with a view to closing down unprofitable routes and opening up new more promising routes. This would be a

longer-term solution that would need an initial feasibility study. The aim would be to do this without the need to increase or decrease the size of the existing fleet and it was felt that although staff might have to be redeployed, there need be no significant redundancies from these changes. This project was placed within the responsibility of the VP of flight operations. This was the project expected to produce by far the greatest savings.

2. Target educational establishments with a marketing drive offering concessionary fares and package deals that would increase traffic on existing routes to places such as Rome, Athens, Cairo and other destinations of high educational value. This project was assigned to the VP of PR and Marketing for further study and future action.
3. Improve the cost efficiency of customer services for private reservations, thus cutting down the cost of making each reservation. It was proposed to move all responsibility for making these reservations to the more cost effective outsourced operation at Callex in New Delhi. This would enable substantial staff reductions in the home office customer services department, but would need investment to upgrade the existing IT systems and communications. It would also require simplification of tariffs, so that only very exceptional cases need be referred back by Callex to customer services at head office for resolution.
4. Carry out a study to improve the efficiency of group reservations from tour operators, revising their contractual obligations and imposing some charges or penalties for empty seats resulting from over ambitious advance block seat reservations not taken up. It was proposed to set up a group services study in the marketing and sales department. The ultimate objective would be to place future contracts with tour operators that would compensate for empty seats. It was further intended that responsibility for making group reservations would be transferred from the head office customer services department to the outsourced service provided by Callex.

Both 3 and 4 above were projects intended to improve accuracy of seat reservations whilst reducing the total customer services staffing and costs. It was decided to run them as a combined project with the title ‘Customer Services Improvement Project’ and the project number 04. This combined project is the subject of this case example.

Strategy for the Customer Services Improvement Project

From here on we are concerned only with the customer services improvement project which, as we have just outlined, combined the third and fourth projects listed above. Thus we have a project that is a mix of revenue optimization and cost reduction, both of which are clearly activities that improve profitability. We summarize below the principal strategic moves that were considered to be necessary:

1. Simplify, tabulate and publish new tariff tables to reduce the number of pricing errors for private customers and enable less experienced (and cheaper) staff to handle customer bookings with less need for referrals to resolve ambiguities. This operation would be led by the VP of customer services.
2. Carry out a study of existing performance in respect of group reservations by tour operators and propose new contract conditions set out against a simplified tariff. Contract conditions to be considered would include a standing charge for each reservation, whether or not the reservation was actually converted into a booking. Other measures included cancellation of block bookings not supported by firm orders (with named passenger lists) before cut-off dates that would allow the airline to fill the seats from other bookings. This study would be conducted within the PR and marketing department.
3. As soon as feasible, arrange for the tour operators' group bookings to be made through the Callex center in New Delhi by operators trained specifically for that task. Thus this process would no longer be carried out by customer services staff at Jet-U-There's head office.
4. These actions would together enable the current 69 staff in head office customer services to be reduced to only 20 staff in a planned and sensitively managed tranche of redundancies. This action would clearly require considerable input from the HRM department to help design redundancy packages, assist with alternative employment and provide counseling. After this project, customer services would no longer handle routine booking inquiries and its greatly reduced team would deal only with complaints or unusual inquiries.
5. Evaluate and update the home office IT systems, both hardware and software, to enable the system to cope with increased communications

with the Callex center in New Delhi. The technical work required for this update would be outsourced to Densys.

6. Densys would also be asked to review and advise on the current communication links between Jet-U-There's home offices and the Callex facility in New Delhi. Efficient fast, high-capacity links would be essential to deal with the increased responsibilities to be placed on Callex and to ensure that the central server at Jet-U-There's offices always contained accurate and up-to-date data (in this case regarding all flight reservations and customer payments).
7. It was agreed that this solution should be pursued with the highest priority, but with due regard to equitable treatment of those whose jobs would be lost or changed.
8. Because of the need to ensure success of this project, expert project management was known to be a prime requisite. Jet-U-There's president did not consider that anyone on the payroll had sufficient project management experience to see this project through, so it was decided to engage immediately an external project management company, Trilok Project Management Services. This company had an excellent track record in managing similar projects for other clients and their offices were only 30 minutes drive away from Jet-U-There's headquarters.

WBS

The WBS for this customer services improvement project is shown in Figure 11.7. This includes the three top levels (total project, first level breakdown and second level breakdown). Note that each item was given a code in a hierarchical structure that would later be used, among other things, for cost collection and control.

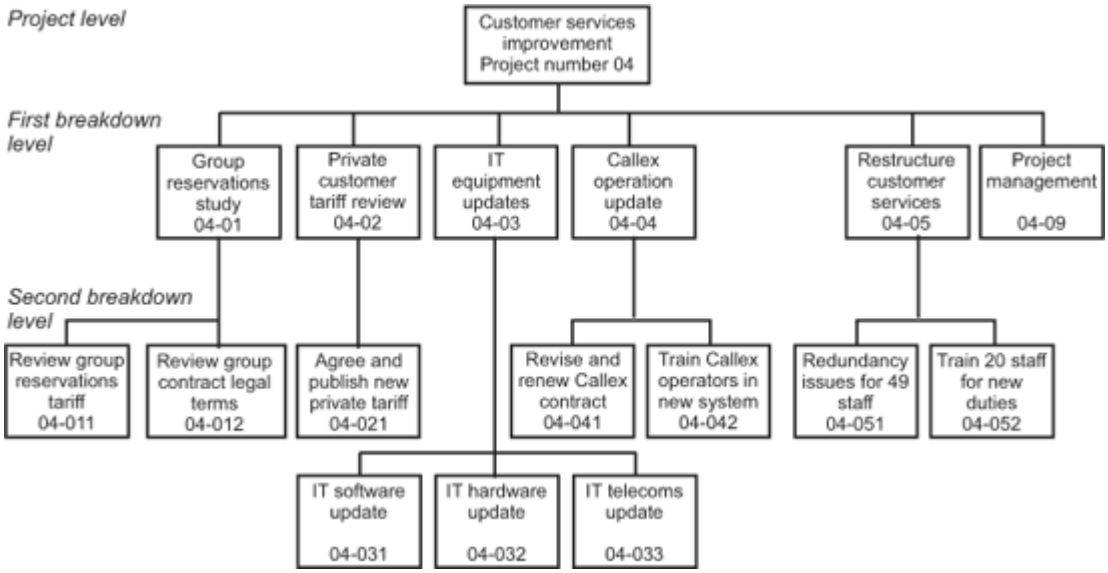

Project level
Customer services improvement Project number 04
First breakdown level
Group reservations study 04-01
Private customer tariff review 04-02
IT equipment updates 04-03
Callex operation update 04-04
Restructure customer services 04-05
Project management 04-09
Second breakdown level
Review group reservations tariff 04-011
Review group contract legal terms 04-012
Agree and publish new private tariff 04-021
Revise and renew Callex contract 04-041
Train Callex operators in new system 04-042
Redundancy issues for 49 staff 04-051
Train 20 staff for new duties 04-052
IT software update 04-031
IT hardware update 04-032
IT telecoms update 04-033

Figure 11.7 WBS of the Jet-U-There customer services improvement project

OBS

Project organization structures are usually temporary, existing only for the life of the project. Before describing this customer services improvement project it is necessary to know how Jet-U-There was organized before the project was authorized. That original organization structure is shown in the top part of Figure 11.8. This is a summary organigram that shows only the most relevant departments and outsourced service providers.

The middle section of Figure 11.8 shows the temporary organization that was set up to run the project. It is clear that a vital task of the project manager provided by Trilok was to ensure that all actions from the project participants would be well coordinated. The urgency of this project, the need for initial confidentiality and the diversity of organizations involved clearly indicated the desirability of establishing a task force. That is usually the best organization structure for driving a management change project through to a successful conclusion. That arrangement was followed here, with the task force set up in its own off site office (a kind of war room) provided at Trilok's headquarters building. There people could work together in close cooperation, with the team members able to report back or consult with their superiors. This project benefited from the advantage of having its task force under one roof.

Members of the task force were chosen by their respective companies for their seniority and ability to make decisions without referral back to their home base. These people were seconded to report directly to the project manager, which involved temporary physical relocation to the war room in Trilok Inc's headquarters building. Thus this task force might also have been described as a secondment matrix. The project manager was authorized to ask for additional people to be seconded to the team for short periods if required.

Locating the project team in its own office provided greatly enhanced project communications. Face-to-face cooperation is always preferable when it can be arranged. Having the 'war room' located away from Jet-U-There's offices also allowed for greater confidentiality, so that unfounded rumors were less likely to be started and staff announcements could be made at the times considered most appropriate by senior management.

The bottom section of Figure 11.8 shows the organization of Jet-U-There as it emerged after the improvement project had been fully implemented. The structure is at first glance essentially the same as that which existed before the project, but the number of people on the payroll in internal customer services has been reduced from 69 to only 20 and more activity has been transferred to the cost effective Callex call center.

Designation of Project Responsibilities

Once it has been decided who should do what in a project, a very useful tool for communicating the agreed decisions is a chart known as a linear responsibility matrix. The preparation and distribution of a responsibility matrix was one of the first tasks of the Trilok project manager, which she did after consultation with all the relevant senior managers. The result is shown in Figure 11.9. This chart is self-explanatory.

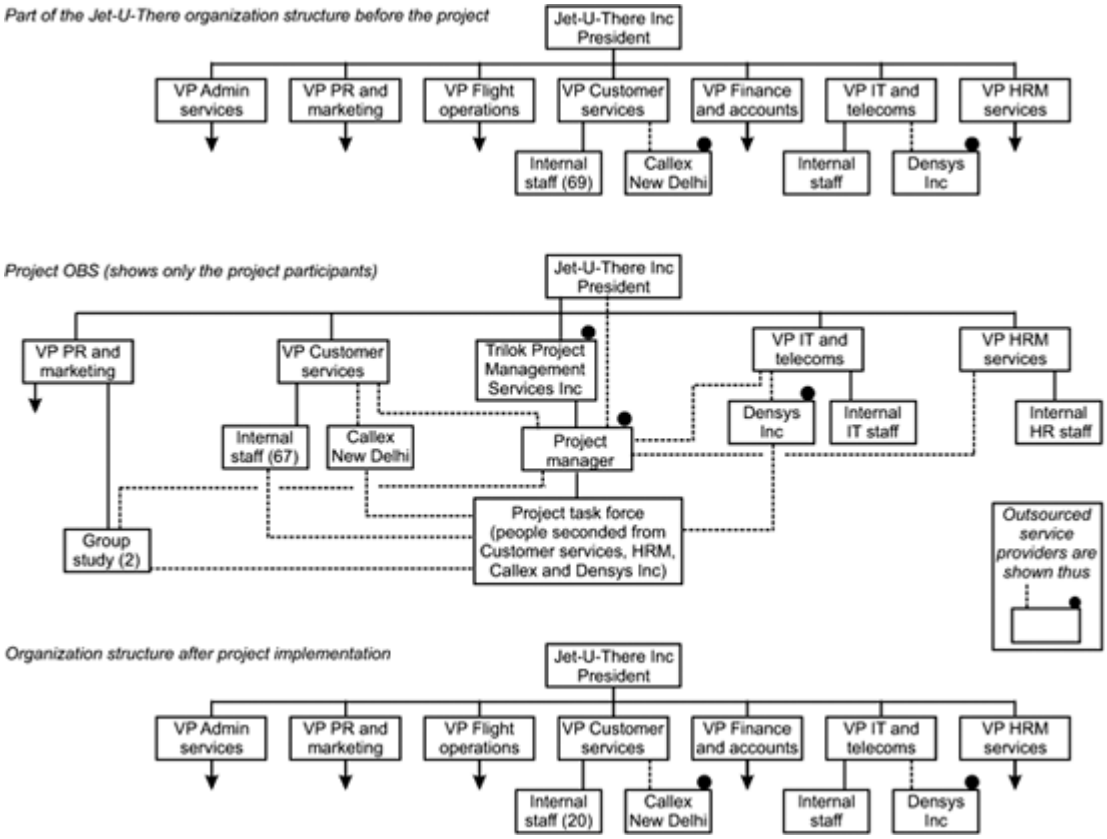


Figure 11.8 Organizational evolution of Jet-U-There before, during and after the restructuring project

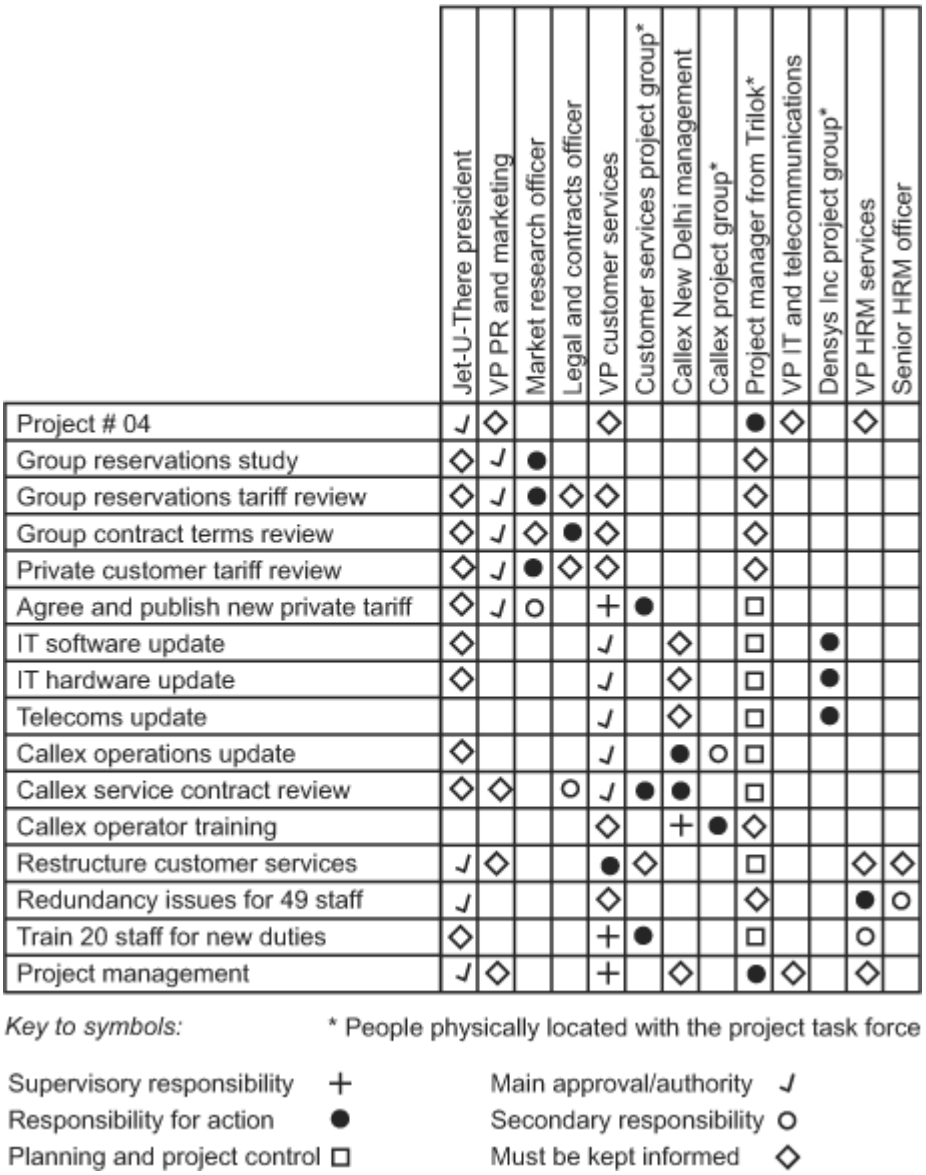


Figure 11.9 Responsibility matrix for the Jet-U-There project

Project Plan

This case example was provided principally to illustrate the work breakdown and organizational breakdown processes described in this chapter, but in Figure 11.10 we show the initial project plan produced by the project manager. She used Microsoft Project software, which was an ideal tool for this process. This plan was based on a critical path network diagram, a methodology that will be explained in the following chapters.

This was a day-to-day work plan that required the inclusion of some tasks from lower levels of the WBS than those given in Figure 11.7. The project manager used the day after her appointment to the project as the starting point for this plan, and the project was considered complete when the following tasks has been finished:

- revised group booking contracts agreed with the major tour operators;
- the customer services department downsized to 20 people;
- routine seat booking services operations transferred successfully to Callex in New Delhi.

The final task was to rearrange the office layout of the customer services department to adapt to the greatly reduced size of the workforce.

Conclusion: The Project Outcome

Schedule The project manager took up her post on 1 August 2011 and work on the project began without delay. The final task was scheduled to finish on 27 October 2011 but the project overran by two weeks. One error made in the original plan was failure to allow for the week needed to set up the war room and temporarily move staff seconded to the task force into it. However, the objective of having the project finished in time for Christmas 2011 flight reservations was achieved.

Project costs and benefits The main cost and benefit aspects of this project can be summarized as follows:

Project costs	
One-off payment to Densys for IT and telecoms services	$ 53 000
One-off payment to Trilok for project management	$ 25 000
Payments to Callex for their seconded staff	$ 5 000
One-off cost of IT hardware upgrade	$ 15 000
Travel and other expenses	$ 4 500
Redundancy package costs	$750 000
Total project cost	$852 500

Time spent on the project by existing staff of Jet-U-There was not considered to contribute to additional costs because their salaries would

have been paid in any case, even without this project.

Changes in annual operating costs

Savings:	
Savings in customer services payroll	$1 180 000
Savings from enhanced tour operator contract conditions	$ 275 000
	$1 455 000
Offset by:	
Increased annual costs to Callex for call center services	$ 400 000
Densys hotline and IT maintenance contract	$ 20 000
	$ 420 000
Net annual saving resulting from this project	$1 035 000

There were also significant benefits from improved customer satisfaction with their reservation experiences. Thus the senior management of Jet-U-There and the project manager rated this project as highly successful.

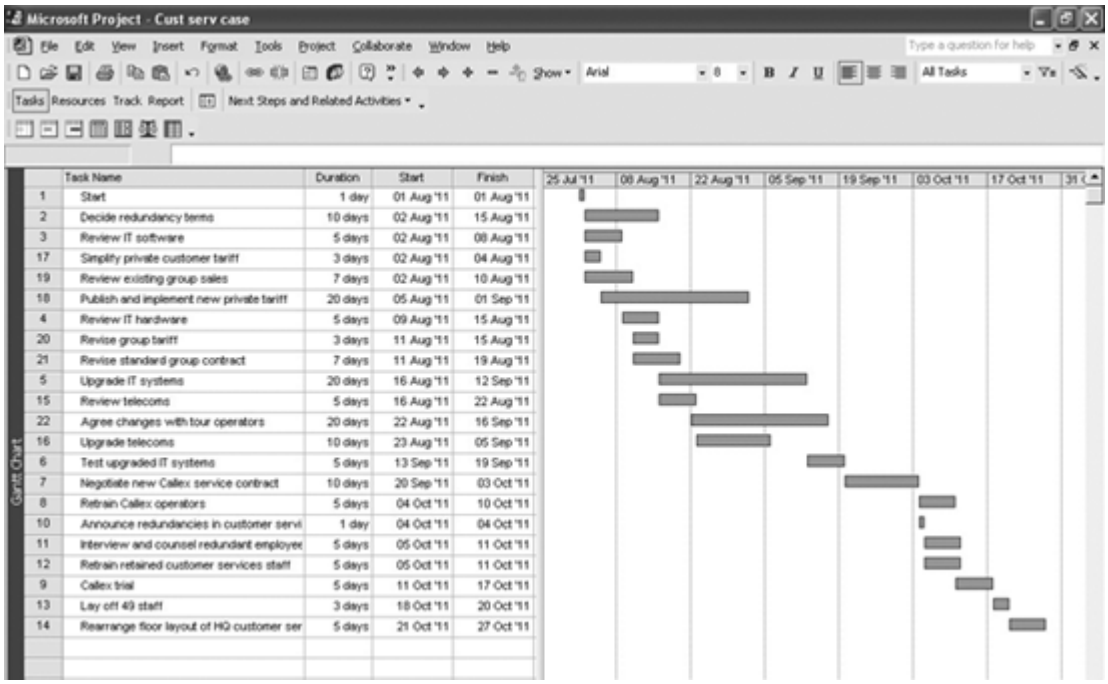

Microsoft Project - Cust serv case
File Edit View Insert Format Tools Project Collaborate Window Help
Tasks Resources Track Report Next Steps and Related Activities
Gantt Chart
Task Name | Duration | Start | Finish
1 Start | 1 day | 01 Aug '11 | 01 Aug '11
2 Decide redundancy terms | 10 days | 02 Aug '11 | 15 Aug '11
3 Review IT software | 5 days | 02 Aug '11 | 08 Aug '11
17 Simplify private customer tariff | 3 days | 02 Aug '11 | 04 Aug '11
19 Review existing group sales | 7 days | 02 Aug '11 | 10 Aug '11
18 Publish and implement new private tariff | 20 days | 05 Aug '11 | 01 Sep '11
4 Review IT hardware | 5 days | 09 Aug '11 | 15 Aug '11
20 Revise group tariff | 3 days | 11 Aug '11 | 15 Aug '11
21 Revise standard group contract | 7 days | 11 Aug '11 | 19 Aug '11
5 Upgrade IT systems | 20 days | 16 Aug '11 | 12 Sep '11
15 Review telecoms | 5 days | 16 Aug '11 | 22 Aug '11
22 Agree changes with tour operators | 20 days | 22 Aug '11 | 16 Sep '11
16 Upgrade telecoms | 10 days | 23 Aug '11 | 05 Sep '11
6 Test upgraded IT systems | 5 days | 13 Sep '11 | 19 Sep '11
7 Negotiate new Callex service contract | 10 days | 20 Sep '11 | 03 Oct '11
8 Retrain Callex operators | 5 days | 04 Oct '11 | 10 Oct '11
10 Announce redundancies in customer servi | 1 day | 04 Oct '11 | 04 Oct '11
11 Interview and counsel redundant employee | 5 days | 05 Oct '11 | 11 Oct '11
12 Retrain retained customer services staff | 5 days | 05 Oct '11 | 11 Oct '11
9 Callex trial | 5 days | 11 Oct '11 | 17 Oct '11
13 Lay off 49 staff | 3 days | 18 Oct '11 | 20 Oct '11
14 Rearrange floor layout of HQ customer ser | 5 days | 21 Oct '11 | 27 Oct '11
25 Jul '11 | 08 Aug '11 | 22 Aug '11 | 05 Sep '11 | 19 Sep '11 | 03 Oct '11 | 17 Oct '11

Figure 11.10 The Jet-U-There customer services project plan produced using Microsoft Project

12
Introduction to Detailed Project Planning

The point has been now reached in these chapters (and in the project life cycle) where the project has been defined, the strategy has been decided, and all the breakdown structures (work, organization and cost) are in place. We know from the project definition and the WBS what tasks must be done and we know from the estimates and budgets what they should cost. But before any work can start it is necessary to deal with the remaining, all pervading and vital dimension of *time*.

The duration of every task has to be estimated, and each task must be placed in its appropriate future time slot. In other words, the planner must decide when each task should start and when it should finish. If materials and components are required, we must know when they will be wanted on the project and when and where the orders should be placed.

We must make sure that no task is scheduled to take place before it is logically possible to do the work. For example, we must not plan to build a wall before the foundations are in place. It would be a stupid planner who scheduled engine installation before the engine mounts were designed, made and installed in the airframe. Such mistakes are easily made in project plans containing thousands of jobs if the appropriate planning methods are not chosen and followed. We must also be certain that people and equipment will be available for each task at its appointed time, which introduces the consequential subject of resource scheduling (demonstrated later in Chapters 15 and 16).

It is apparent that no sooner have we overcome one set of problems than more arrive to confront the hard-pressed project manager. Yet again we are faced with decisions that have to be made in a logical sequence, reinforcing the argument stressed throughout this text that much of project management is about commonsense and logical thought. A good analogy here is the mathematician faced with the problem of an equation with many unknown variables. The novice will be over-faced and might easily capitulate. The

expert, on the other hand, will solve those variables one at a time rather than attempting the impossible task of trying to solve them all at once. Project managers have a somewhat similar task. They must take all the project scheduling decisions in the appropriate sequence if an apparently very difficult problem is to be reduced to something that is within human capability. Figure 12.1 reinforces this message and provides some signposts.

Step	*Action*	*Relevant chapters*
1	Define the project and its scope—know what the project will deliver	3
2	Decide the project strategy—know how the project will be carried out	4
3	Establish the WBS—list all the known tasks and code them	10
4	Put the tasks in their most logical, practical sequence	12, 13
5	Estimate the task durations - how long should each task take?	12, 13, 14
6	Determine the earliest dates on which each task could start and finish	12, 13, 14
7	Establish task priorities and allocate resources accordingly	15, 16

Figure 12.1 Logical, sequential steps necessary to reduce chaos to sensible scheduling

Three fundamentally different planning methods are available to the modern project manager. These are:

1. The diary method, which means picking target dates out of the air and attempting to work to them;
2. Bar charts, also very often known as Gantt charts;
3. A family of methods that are collectively known as critical path network analysis.

A DEMONSTRATION CASE EXAMPLE

The case example which we now introduce has been invented for its simplicity and suitability. It is sufficiently simple to allow the plans and other reports to be shown clearly in these small pages, yet is substantial enough to demonstrate the possible planning methods. Put another way, this project is

small enough for amateurs to handle, but big enough to prove a disaster for its investors if it is not sensibly planned and managed.

Introducing the 4J Airstrip Project

Four city farmers, Joe, Jake, James and John are neighbors on mixed farms who rely on well-paid jobs in downtown offices for their principal sources of income. Those city jobs keep them busy during weekday office hours, so they rely heavily on their families and a few part-time workers to perform the daily routine farm work. These city farmers are good friends and they cooperate with each other in many ways, such as sharing each others' farm machinery and pooling resources at busy planting and harvest times.

All the farmers have pilot's licenses and each owns a small general aviation airplane. Joe owns a Cessna C172 RG, Jake bought a used twin engine Piper Seminole a few years ago, James proudly showcases his glass cockpit Diamond DA-20, and John has a well maintained classic, a CAP 10. They fly frequently and independently for a mix of business and leisure but unfortunately have to use an airfield that is 20 miles away on the other side of the nearest town. These four city farmers have decided to pool their labor and some money to create a private airstrip on their own farmland, calling it the 4J field after the initials of their first names. The four farms are close to each and share some common boundaries. There is a suitable site that will take a few acres of grazing land from one of their farms to create a small airfield within easy reach by 4x4 vehicles from the four farmhouses.

The farmers believe that they, their families and their hired farmhands will be able to do most of the work in creating the airfield themselves to save expense. Between them they have a carpenter's shop, equipment and tractors with attachments for hauling, lifting, earthmoving, trenching, digging, post planting, grass mowing, rolling and other useful equipment. They recognize, however, that one or two tasks will have to be let to specialist sub-contractors.

Project Definition

The farmers will mark out the airfield site and erect post and wire fencing around its perimeter to keep out farm animals and deter other intruders. By making new large doors, an existing barn will easily convert to a hangar that

can accommodate the farmers' four small aircraft, with room to spare for occasional visitors. The farmers have decided to locate their simple airfield facilities near the hangar, so they will create a concreted area for this purpose, which will extend in front of the hangar to provide a small apron.

A purchased concrete prefabricated garage will provide parking for up to four 4x4 vehicles, and the farmers can erect this themselves near the hangar. An underground gas tank will be installed so that the planes can be refueled, and that will need pipes, valves, vents and a fuel pump that can meter gallons (so that the farmers can share the fuel costs fairly). A specialist contractor must be hired for some of this work for obvious safety reasons.

A single 2000ft × 50ft grass runway will be created by ensuring that all boulders are removed and felling the few trees that lie on or near the strip. The existing pasture land is level, except for two small hillocks that will have to be bulldozed flat. Then the disturbed areas will need turfing over, and finally a couple of months spent in mowing and rolling should create a serviceable surface. It is anticipated that this runway can be converted to asphalt in a few years' time when more funds become available.

No separate taxiways will be installed, but grass turning circles will be provided at both ends of the runway. However, areas where concentrated plane and vehicle movements are expected (such as the hangar apron, refueling point and short road from the entrance gate for cars and the fuel supply tanker) will be concreted. Concrete will be poured by a contractor using ready-mix tankers.

Electric power can be obtained by laying an armored underground cable from the nearest farmhouse, which is only 50 yards away and has adequate unused capacity. A clean water supply can be piped from the same farmhouse.

The farmers do not usually fly at night but they will feel safer if they install 40 sodium runway lights (20 along each side of the runway at ground level) as a precaution against late movements or unexpected poor visibility. These runway lights will be switched from the nearby farmhouse, where the ground radio set will also be kept. That farmhouse will always be occupied by one or more people capable of monitoring and operating the radio. The runway lights will be connected via a relay among the hangar electrical switchgear, so that only a light switching cable will be needed from the farmhouse.

Some consumable spares and hand tools will be kept in the hangar, but the planes will have to be flown to the municipal airport for all inspections, servicing and repairs.

This chapter and the next examine various ways in which these farmers might set about planning their small project.

PLANNING THE 4J AIRSTRIP PROJECT BY THE DIARY METHOD

Businesspeople with no previous project management experience often set about planning work in their companies by what we might call the diary method of planning. The people involved arrange a meeting, discuss what needs to be done, agree the actions needed by those present and note the 'to be done by' dates in their diaries, They might also issue minutes of the meeting to record the actions and target dates agreed. Thousands, if not millions of such meetings are taking place in companies around the world all the time.

This diary method is fine for planning simple actions that can be undertaken in a few days or a couple of weeks, but the trouble comes when the participants fail to recognize that the activities they are trying to plan really constitute a project. Then they need instead to adopt a project management approach. We can illustrate the false 'diary planning' approach using the 4J airstrip project as an example.

The Initial 4J Airstrip Meeting

Once the four farmers had the idea of the jointly owned airstrip they held a March meeting to agree how to arrange ownership of the airstrip, and how to share the work and cost during the coming spring and summer. All agreed that ownership would be shared, with a special bank account opened so that accounts could be kept and each farmer could contribute to the costs of the project and the running expenses of the airstrip. These four farmers were such firm friends that these arrangements were made on an informal basis, and the meeting itself was conducted more on the lines of a friendly get-together rather than a business meeting. For this and the following chapter we

shall ignore costs and budgets and concern ourselves only with the planning and scheduling aspects of this project.

The farmers discussed the work that would need to be done. They made a list of all the known tasks and agreed to split the work between them in the way that we have shown in Figure 12.2. As project managers, we know of course that they had created a WBS, but to those farmers it was just a task list showing how the work might be shared. They took into account their different personal capabilities and also those of their farm workers in deciding who should do what. For example, John had a backhoe tractor on his farm that would be capable of digging the pit for the fuel tank, whilst Joe had a tractor with a bulldozer blade that could cope with most of the site clearance and leveling work. Each farmer made a rough estimate of the time needed to do his share of the work and they agreed to meet again at the end of April (and monthly thereafter) to discuss progress.

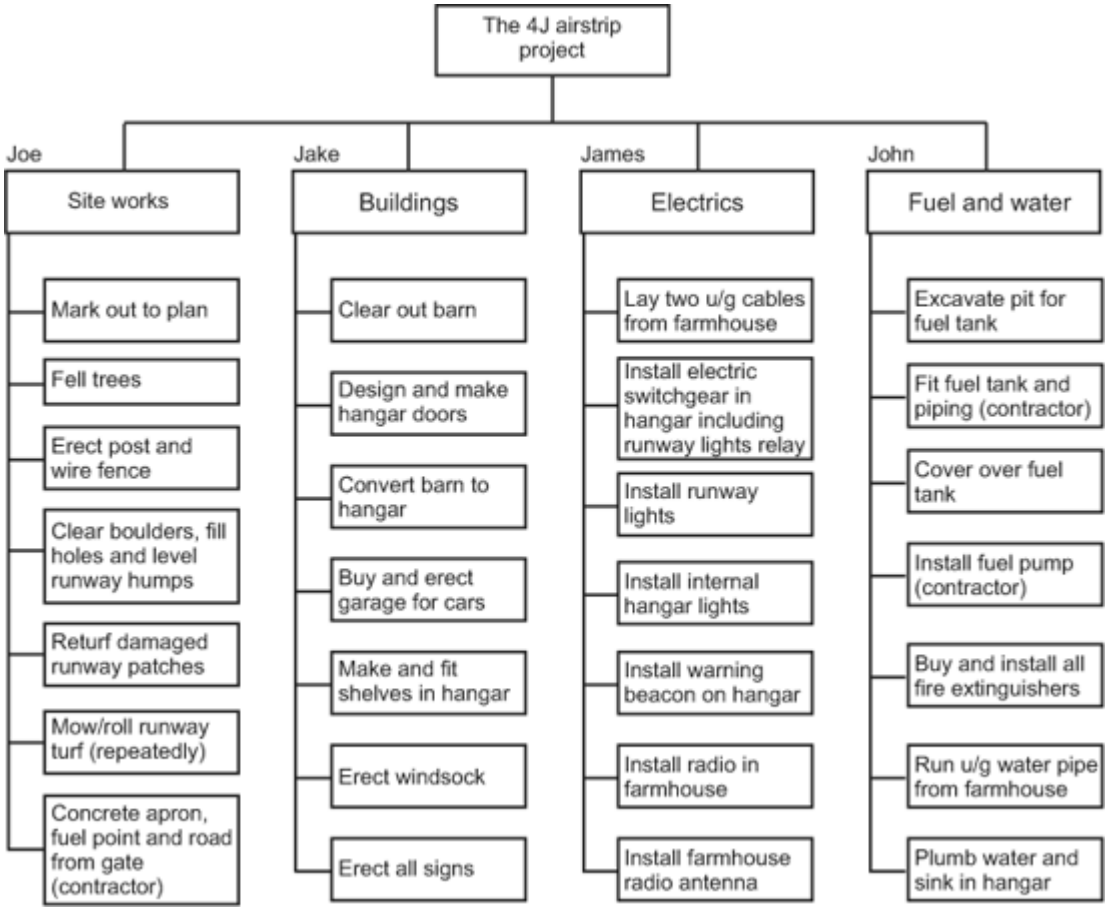

The 4J airstrip project
Joe
Site works
Mark out to plan
Fell trees
Erect post and wire fence
Clear boulders, fill holes and level runway humps
Returf damaged runway patches
Mow/roll runway turf (repeatedly)
Concrete apron, fuel point and road from gate (contractor)
Jake
Buildings
Clear out barn
Design and make hangar doors
Convert barn to hangar
Buy and erect garage for cars
Make and fit shelves in hangar
Erect windsock
Erect all signs
James
Electrics
Lay two u/g cables from farmhouse
Install electric switchgear in hangar including runway lights relay
Install runway lights
Install internal hangar lights
Install warning beacon on hangar
Install radio in farmhouse
Install farmhouse radio antenna
John
Fuel and water
Excavate pit for fuel tank
Fit fuel tank and piping (contractor)
Cover over fuel tank
Install fuel pump (contractor)
Buy and install all fire extinguishers
Run u/g water pipe from farmhouse
Plumb water and sink in hangar

Figure 12.2 WBS for the 4J airstrip project

Before leaving the meeting they agreed the following dates for the biggest tasks and created what we have termed a diary plan by entering these dates in their four personal diaries:

Task	*Target finish date*	*Responsibility*
Mark out site, fell trees, erect fence and gates	End of April	Joe
Make doors and convert barn to hangar	Mid-May	Jake
Repair and prepare the runway turf	Late summer	Joe
Hire contractor to concrete roads and apron	End of July	Joe
Connect electric power	End of May	James
Finish lighting installations	End of July	James
Install radio and antenna at nearest farmhouse	Mid-August	James
Pit prepared ready for fuel tank	End of June	John
Fuel tank and pump ready for use	End of July	John
Water laid on	End of June	John
Buy and erect garage for cars	Before August	Jake
Runway ready for first flight	End of August	All

Notice that, like many such diary plans, some of the dates are expressed in vague terms, and that the breakdown of tasks is coarse when compared with the WBS shown later in Figure 12.2. Further, it was left as a point of honor that these farmers would keep to their agreed schedule, and there was little opportunity for them to meet between times to check on each other's progress.

Progress Against the Diary Plan

City farmers are busy people, with their working lives shared between their daily office jobs, their farms, their families and their leisure pursuits. Their busy travel schedules meant that they do not meet their colleagues as often as they would like. Thus, after this 4J airstrip project started their busy personal commitments meant that it was difficult for them all to be free at the same time. Thus even their progress meetings were delayed beyond the scheduled dates and their second meeting was held not at the end of April as planned but nearer to the end of May.

Inevitably, when the four farmers compared notes they found that progress had been disappointing. So they discussed and agreed a new set of target dates, wrote those in their diaries, arranged the date of their next meeting and left to continue their separate busy lives. This process was repeated at their

next, third, meeting in July, when it became apparent to all concerned that something needed to be done if the project were going to be ready before winter came to freeze the ground and prevent further work.

That cyclical pattern of broken promises, apologies, promises to do better, revised dates and further broken promises is typical of diary planning. This scenario is played over and over again in boardrooms and conference rooms through the business world. The causes are as follows:

1. the schedule pays insufficient regard to detail, so that target dates are too far apart;
2. this coarse planning detail does not provide benchmarks at sufficiently close intervals for progress checks;
3. the target dates are made without sufficient thought about the work involved and possible difficulties;
4. there is no person keeping a regular check on everyone in the long intervals between progress meetings.

Thus, not surprisingly, we do not recommend the diary planning method for aviation projects. Something better is clearly needed.

A SIMPLE REMEDY FOR THE 4J AIRSTRIP PROJECT

Improved Project Organization

By the end of June the farmers recognized that something had to be done, so they called in the help of one of their daughters, Jill, who could be available at the site full time to monitor progress, remind all the farmers of their obligations and help by ordering materials and arranging sub-contracts. Jill had some business training and work experience from her ongoing college studies. She was able to draw up a simple bar chart (or Gantt chart), and then act as a coordinator for the project to ensure that tasks took place at their scheduled times.

Introduction to Gantt Charts

Gantt charts need little explanation and no training because anyone who can understand a holiday wall chart or even a calendar should be able to

understand a project Gantt chart. Gantt charts are named after their progenitor, the American industrial engineer Henry Gantt (1861-1919). They are also known widely as bar charts and until the advent of more flexible computer systems they were used for a wide range of industrial planning purposes, and for work rosters to schedule people at work. We have already used these charts in earlier chapters to depict the timing of different phases in project life cycles. See, for example, the top part of Figure 1.2.

Gantt charts are always drawn to a linear time scale, using days, weeks, months, years or other units to suit the particular project. They are excellent visual aids and their effectiveness can be enhanced by the use of different colors.

Gantt charts can be used for very simple resource scheduling because the amount of any particular kind of resource needed in a given time period can be calculated by adding the number of times that tasks needing that resource appear in each period column. Before the advent of computers this was the only scheduling method possible, and we used to plan using Gantt charts set up on wall-mounted pegboards that allowed the tasks to be represented by colored card or plastic strips. These strips could be moved horizontally on the chart to achieve the best possible resource usage pattern. Another version of these charts used Lego bricks, and yet another idea was based on magnetic strips stuck to a steel back plate, rather in the manner of fridge magnets. The length of each strip was directly proportional to the estimated duration of its task, and the color could be chosen to represent a particular kind of resource or skill (for example electricians or mechanical fitters).

Even in the wider industrial and commercial world of larger projects, senior executives and others unskilled in the project management arts often prefer to be given Gantt charts in reports because the more powerful critical path network planning methods (discussed below) need some training before lay people can interpret their charts. All competent project management computer programs can convert critical path network diagrams into Gantt charts, with or without showing all the complex inter-task dependencies.

Gantt Chart for the 4J Airstrip Project

Jill, as the newly appointed project coordinator of the 4J airstrip project, took immediate and urgent note of the new (delayed) delivery times agreed by the four farmers at their end-of-June progress meeting Determined to

prevent further program slippage, Jill drew up a Gantt chart using this latest set of agreed dates and gave a copy of this chart to each of the four managers. Her Gantt chart is shown in Figure 12.3.

It is immediately obvious that the Gantt chart gives a far clearer visual impression of the project laid out against time than the original crude diary attempt. Now Jill has a scale against which to issue reminders to the four farmers and ensure that they or their employees and helpers keep to the schedule. By placing a vertical dateline cursor on the chart (a Perspex ruler is ideal for this purpose) Jill and each of the farmers can clearly see what jobs (or proportions of those jobs) should have been accomplished on the review day in question.

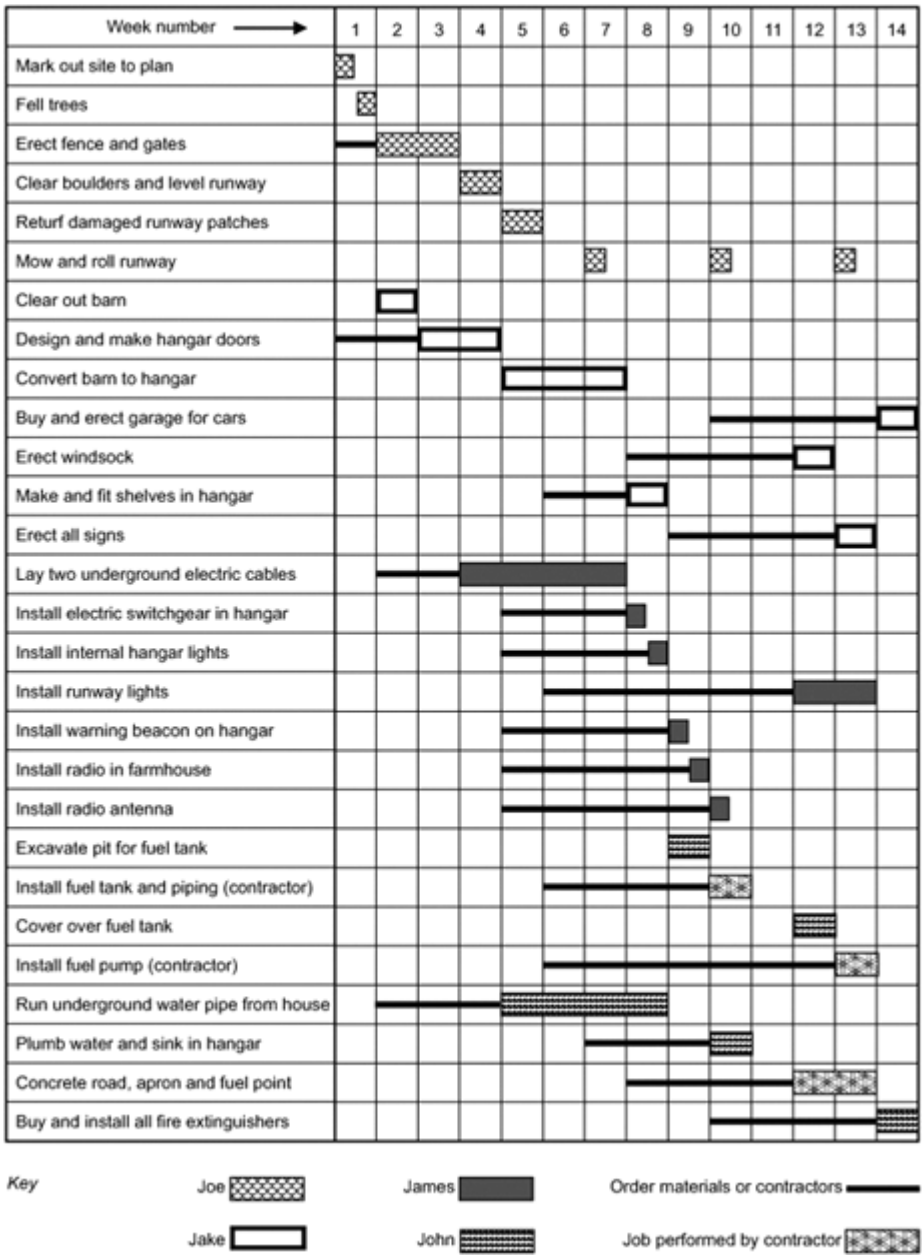


Figure 12.3 Gantt chart showing revised plan for the 4J airstrip project

Now Jill also has a schedule for arranging orders for project materials and equipment, and for arranging work from the specialist contractors. That should ensure that orders are placed in time for the materials and for specialist contractors to be ready and available on the airfield site when they are needed.

We can assume that, from the time of Jill's appointment as planner and coordinator to the 4J airstrip project, progress can be improved dramatically and that the project stands a far better chance of finishing on time. This

combination of Gantt chart planning and coordinated project management organization can be adequate for very small projects but not for any aviation project of significant size.

LIMITATIONS OF GANTT CHARTS

It is apparent from Figure 12.2 that coding the bars representing jobs allocated to the four farmers shows which farmer has principal responsibility for supervising or actually performing each task. This helped the planner (Jill) to avoid overloading any farmer by giving him two different jobs at the same time. This is, in fact, a simple case of resource scheduling. Resource scheduling will be described in much greater detail in Chapters 15 and 16, but this simple chart was adequate for the small 4J airstrip project and at one time Gantt charts on adjustable boards were the only tool available to project managers for matching tasks to the resources available.

Where a project has hundreds of different tasks, it becomes more difficult to envision the logical working pattern, both when drawing the chart and when subsequently trying to read it. It then becomes very easy for the planner to make mistakes, such as scheduling a test flight before the test pilot has been engaged, showing a wind tunnel test before the scale model is ready, or showing a job taking place before its materials have been ordered. Planners have tried to overcome these difficulties and avoid such mistakes by drawing link lines from the end of each task to its succeeding dependent tasks. They have then created documents known as linked Gantt charts.

However, except in the very simplest cases, a Gantt chart can become very cluttered and difficult to follow when all the inter-task links are added and it is usually best to hide them. Critical path networks diagrams provide the superior notational methods that overcome these problems and allow planners to plot the preferred sequence of all the tasks in a project and also to display the logical dependency links between task starts and finishes. In our Gantt chart of Figure 12.3 those links were implied, but in a critical path network they can be denoted clearly and specifically. Critical path network planning is introduced in the following chapter, where we shall revisit the 4J airstrip schedule.

13
An Introduction to Critical Path Network Analysis

Critical path network analysis is a term that covers a number of project planning methods that originated around 1950. Different systems emerged in Europe and North America but all these methods depended on the use of diagrams in which all the identifiable project tasks or expected events are depicted as symbols arranged in a pattern that determines their practical chronological sequence.

Whereas Gantt charts are usually good visual aids that can easily be understood on sight, these new critical path network diagrams needed some explanation, training and considerable encouragement before people could understand and use them. But the striking project management improvements achieved using critical path networks when compared with earlier planning methods has led to their adoption as the tool preferred by professional project managers for planning and progressing projects in most industries. Progress in the adoption of critical path network analysis accelerated during the 1960s and 1970s, greatly helped by the widespread availability of digital computers. For those interested generally in the early history of project management development, Morris (1994) is a very good place to start.

A GENERAL INTRODUCTION TO CRITICAL PATH PROJECT PLANNING

Whatever the variant of critical path planning one chooses to use, the heart of the methodology is some form of a network diagram. The two most popular versions will be described and illustrated later in this chapter, but all network diagrams share some common characteristics.

Unlike Gantt charts, network diagrams do not have to be drawn to any kind of timescale. They simply need to show all significant project tasks or planned events in their preferred logical sequence and juxtaposition, together with the logical links that connect them. It is not for nothing that critical path

network diagrams are also known as logic diagrams, and those who compile and use them will do their job best if they have some skill in logical reasoning. People who enjoy solving puzzles, playing chess or who achieve high scores at intelligence quotient tests will probably have the appropriate aptitude.

Fully serviceable networks can be sketched freehand, although it is better if they can be laid out with some care (as in Figures 13.4 and Figure 13.9 for example) because that helps to prevent errors and will be found useful if changes have to be made. Unlike Gantt charts, network diagrams do not ever need to be drawn to any timescale. The linking arrows and other symbols can be drawn to any convenient size, and they do not even need to be all the same size.

A few computer programs can plot network diagrams to a specified timescale if desired but the printed results tend to be unsatisfactory and occupy very large areas of paper. If a timescaled project plan is wanted (some senior executives like them) it is far better to begin with a normal unscaled network and allow the computer to convert that to its Gantt chart equivalent. That conversion function is readily and rapidly available in most modern project management software and indeed with some programs (including the ubiquitous Microsoft Project) the initial default on-screen plan will appear in the form of a linked Gantt chart. However, network logic diagrams plotted out to a timescale are not in common use, are unnecessary, and are therefore not demonstrated in this book.

One great strength of network analysis is that it allows relative task priorities to be assessed and quantified, based on a combination of the logic pattern and the estimated durations of all the tasks. Those tasks that cannot be delayed without endangering project completion on time are identified as critical, and all other tasks can be ranked according to their quantified priority or degree of criticality.

Critical path network analysis is a method that lends itself very well to computer processing and the filtering, sorting and targeted reporting of project data. Managers can be given reports containing data only for tasks within their own responsibility or direct interest.

When a plan has to be redrawn and recalculated to suit changes in the scope of a project or to reflect progress, this is no longer the dreadful chore that it once was. In those olden times the methods used relied on adjustable charts set up manually and displayed on wallboards, Scheduling projects on

those boards was, to some, an interesting pastime but rescheduling was always a difficult and tedious chore. Now, thanks to the marriage of critical path networks and computers, project schedules can be very flexible to progress events, risk occurrences and changes, so that updated plans can be rapidly calculated and issued.

Networks cannot, by themselves, be used for resource scheduling. In this respect Gantt charts are more user friendly and easier to understand, provided that the number of activities is very small (say below about 100). However, critical path network analysis, with its identification of priorities and ability to highlight critical jobs, is a far more powerful base for the resource scheduling process. With suitable software the computer becomes a powerful and fast resource scheduling tool that can handle many thousands of tasks, with many more different kinds of resource than anyone could ever need in practice. All that processing power will take account of both the logical, practical task sequence and the priority data obtained from the critical path network.

Two Fundamentally Different Network Notation Systems

The different critical path network methods in use today fit within one or other of two principal groups, determined principally by the way in which their diagrams are drawn. These two groups are:

1. **The activity-on-arrow system** (often simply called arrow diagrams or ADM). The principal characteristic of this method is that each network junction (node) represents an identifiable event in the life of a project, whilst each of the arrows joining those nodes represents the logical link or task needed to advance the project from one task to the next. The event nodes are usually drawn as circles, and each event is numbered to give it a unique identity.
2. **Activity-on-node networks.** Here, each node represents a project task or activity and the lines drawn between the nodes are simply logical links. By far the most common example of this method now goes under the name of the precedence system (which is sometimes abbreviated to PDM for precedence diagram).

There were several earlier network diagram systems that used variants of these methods but they have all fallen out of use and will not be described in this book. Some early arrow network analysis systems had their own differentiating names, such as CPA (Critical Path Analysis), CPM (Critical Path Method) and PERT (Program Evaluation and Review Technique). With the passage of time, their differences have been clouded and forgotten, which is generally no cause for concern. However, some caution must be exercised when talking about PERT networks. Originally applied only to arrow diagrams, PERT is now used to describe also activity-on-node networks. However, the important fact about PERT that is often forgotten is that it takes a probabilistic view of schedules (looking at the chances of results being obtained), rather than the deterministic outlook of all the other systems. PERT will be described in Chapter 14.

The terms ‘activity’ and ‘task’, although occasionally used by some authorities and software designers with different meanings, are treated as interchangeable synonyms in practice (and throughout this text).

Interface Between Critical Path Project Schedules and Manufacturing Plant Schedules

Most planning and work scheduling systems used in manufacturing plants and materials control are really network analysis methods (although they are not usually named or regarded as such). These highly detailed scheduling systems are, of course, essential for controlling the day-to-day tasks of people and machines (along with inventory management) in aviation manufacturing plants.

In the ideal marriage between project and plant management these more detailed manufacturing and inventory management systems will use the project schedule data obtained from project critical path analysis as a broader schedule envelope, within which all the myriads of materials purchases and daily (even hourly) manufacturing operations must be performed.

Detailed project manufacturing schedules lie generally outside the scope of aviation project managers (and this book) because their use falls squarely within the remit of managers, production controllers, materials managers and industrial engineers in manufacturing plants. Project managers may not even be aware of these manufacturing systems, but many will surely depend on

others who must use them to deliver the materials and manufactured components needed for their projects.

Which Project Network Analysis System Should be Used?

The precedence diagram is now by far the more popular choice for networks that are going to be processed by computer. One reason for the popularity of precedence diagrams is that they appear more user friendly to people with no planning experience (which includes most senior executives) because they bear a close resemblance to engineering flow charts. They are easier for the novice to follow than their arrow diagram counterparts.

Although arrow diagrams can be contrived with some difficulty to show complex relationships between different activities (such as activities whose starts and finishes can be allowed to overlap) precedence networks more easily allow a range of more complex constraints to be shown and planned. This aspect of critical path networks will be described later (in Chapter 14).

Another very strong reason for the use of precedence networks is that almost all modern computer software will only accept precedence notation. The only competent internationally available exception of which we are aware is Micro Planner X-Pert, which can accept both arrow diagram and precedence diagram networks.

Why, then, does arrow notation survive and why describe it in this book? The good reason is that arrow notation remains a very useful skill for the planning professional. Both of us have found arrow networks the easiest and fastest to sketch in brainstorming and planning meetings (where the time of senior delegates is always at a premium). Arrow networks can be sketched very roughly and quickly, but precedence networks need far more drawing care, which takes time and space on the paper sheet. A useful tip for sketching arrow networks is to have on hand some soft pencils, a long Perspex ruler or straight edge, a stencil for drawing the event circles and (perhaps the most important network diagram tool of all) an eraser. Those simple tools will help to keep the sketch neat and legible as it develops. A further tip is to rule or print with feint lines a square grid, say spaced at two inches, all over the sheet or roll of paper on which the network is to be sketched. That, too, can help to keep the sketch tidy and legible. In most cases, once the logic has been sketched in arrow notation it is a simple job

for the planner to convert it to precedence, at relative leisure after the meeting, when the time comes to input the data to the computer.

We have been told by an eminent professor that precedence networks can be compiled quickly using 3M Post-it Notes. These can be stuck on to a flip chart or roll of paper, with each sticky note representing a project task. No doubt each of these Post-it Notes could be preprinted or rubber-stamped with the rules and boxes needed for precedence network tasks (we shall describe those later in this chapter). That might work well for a network with about 50 activities but can you envision what such a chart might look like after a typical brainstorming session (in which a project might have several hundred or even a thousand tasks)? Not very practical.

Precedence logic is particularly easy to draw and edit on the computer screen but the small screen size compared with large sheets or rolls of drawing paper limits the size of network that can be seen as a complete 'map'. Each computer screen image is more like a page in an atlas, so that the complete journey from project start to finish through all possible paths cannot be seen without much tedious scrolling up, down and sideways. The planner sitting at a desk, transcribing data from a paper sketch, can easily cope with that problem, but would it work so well in a busy planning meeting?

Which Network Diagram System Would you Prefer to Read About?

Everyone involved with project management should be aware of both arrow and precedence diagrams. Both are described in this book. It is a useful personal attribute to be able to make an initial project plan using either an arrow diagram or a precedence diagram according to the particular circumstances of the planning session.

So both arrow and precedence networks have their own particular advantages and disadvantages. For that reason we shall now describe both methods, giving each method its own self-contained section in the following paragraphs. That will inevitably lead to some text duplication, but it will also give readers who are determined never to draw an arrow diagram in their lives the opportunity of skipping the following main section of this chapter.

ACTIVITY-ON-ARROW NETWORK DIAGRAMS

The Arrow Logic Diagram

The heart of any activity-on arrow system is the arrow diagram or 'network', itself. This differs from the more familiar Gantt chart in several important respects. Arrow diagrams, in common with all other network methods, are not drawn to scale. Every network is, however, constructed with careful thought to show as accurately as possible the logical relationships and interdependence of each activity or task with all the other activities in the project. Indeed, it is for this reason that networks are sometimes called 'logic diagrams'.

Activities and events in arrow diagrams Figure 13.1 shows a very simple arrow diagram. Each circle represents an event in a project. An event might be the start of the project, the start of an activity (or task), the completion of a task or the end of the project. The arrow joining any two events represents the activity, task or time delay that must take place before the second event can be declared as achieved. Events are usually shared between tasks, so that a single event might signal the completion of one or more tasks and the start of one or several more tasks. In Figure 13.1 it can be seen that that 10 events are linked by 11 activities.

Jargon We prefer to avoid technical jargon as much as possible but readers may meet other terms that describe the network event circles and activity arrows. These strange terms have their origins in the mathematical theory of networks. In this alternative language, the circles are termed 'nodes' and the arrows become 'arcs'. The event at the tail of the arrow (the activity's preceding event) is called the 'I' node for that activity, and the event at the arrowhead (the succeeding event) is called its 'J' node. Therefore arrow networks are occasionally referred to as 'IJ networks'. Project people do not need to know or use this jargon but the terms might be found in the literature.

Direction By convention, activity arrows are always drawn from left to right. This means that the arrowheads are not strictly necessary and could be omitted. However, when a network is altered or when space is limited an arrow might have to be drawn vertically or even from right to left. In those

exceptional cases the arrowheads *must* be shown so that there can be no ambiguity about the direction of any arrow.

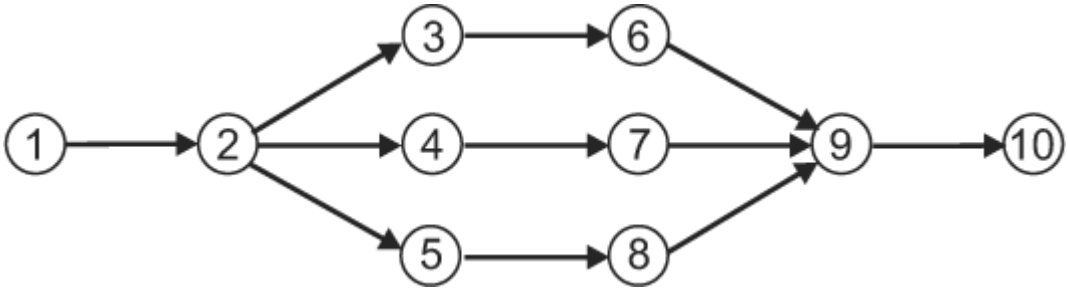


Figure 13.1 The main elements of an arrow diagram
Each circle represents an event, such as the start or finish of one or more project activities. The arrow joining any two events denotes the activity or time needed for the project to proceed from one event to the next. The number written within each circle is the identifier for the event. In addition to the activity description (not shown here) each activity is identified by its preceding and succeeding event numbers. The first activity here, therefore, would be called activity 1,2 or 1-2. No activity can start until all activities leading into its preceding event have been finished. Activity 2-4, for instance, cannot start until event 2 has been achieved or, in other words, until activity 1-2 has been finished. Similarly, activity 9-10 cannot start before event 9 has been achieved, which means that activities 6-9, 7-9 and 8-9 must all be finished. Networks do not need to be drawn to any timescale and the length of an arrow has no significance. It is always best, as here, to start and finish a project network at single events.

Scale Unlike Gantt charts, network diagrams do not have to be drawn to any scale. The length of the arrows and size of the event circles have no significance whatsoever.

Identification numbers in arrow diagrams The numbers written in the event circles are identifier codes that label the events: they allow the events and their associated activities to be referred to without ambiguity. In Figure 13.1 the arrow from event 1 to event 2, for example, can be described as activity 1,2, or 1-2 or 1→2.

Logical activity dependencies and constraints in arrow diagrams In any arrow diagram, no event can be considered as achieved until all the activities leading into it have been finished. Activities leading out of an event must wait for that event to be achieved before they can start. This can be demonstrated by reference to Figure 13.1. Event 9 cannot be considered as being reached or achieved until all three activities leading into it from the left have been achieved. Only when event 9 has been achieved, and not

before, can activity 9-10 start. Similarly, activities 2-3, 2-4 and 2-5 must all wait until activity 1-2 has been finished before they can start.

Now, applying the arrow diagram method to an everyday 'project', suppose you want to erect a windsock on a pole. If you were misguided enough to consider an arrow diagram necessary for this tiny project, the result would look something like the sequence shown in Figure 13.2. Notice that the estimated duration for each arrow is written above or below its arrow. The description of each activity (or task) is also written along its arrow. Because space is often limited in network diagrams and computer reports, planners become adept at abbreviating descriptions. The interdependence of activities is clear in this case, and only one sequence is possible. The pole cannot be placed in the hole before the hole is there, and there would be little point in pouring concrete into the hole before putting the pole into it.

Activity duration estimates and descriptions One of the most important tasks in any planning operation is to estimate how long each task will take. This is an estimate in units of elapsed time, not necessarily connected with labor-hours or other units of work. We are concerned in this instance only with the passage of time, so that the time taken for concrete to set becomes significant, even though it involves no work and is not strictly a task. So, here are the estimated durations, in daytime working hours, needed to finish each activity in the windsock project.

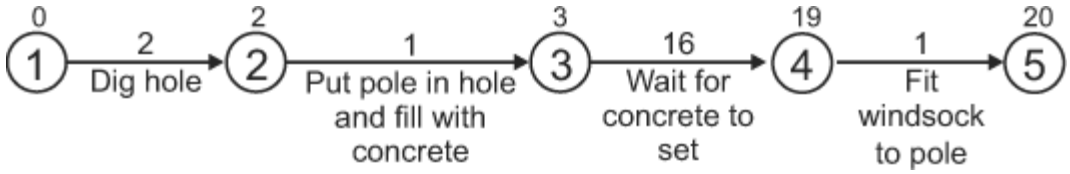


Figure 13.2 Windsock project using arrow notation

The numbers written above the activity arrows in this extremely simple example are the estimated task durations. Hours have been used here, with 8 working hours equivalent to 1 calendar day. Any time units can be used provided that the same units are used throughout the network. Days or weeks are more often used in aviation projects. The number written above each event circle shows the earliest possible time by which the event could be achieved. Thus this project has been planned to take 20 working hours which, when working 8-hour days, is 3.5 days.

Activity	*Description*	*Estimated duration*
1-2	Dig the hole	2 hours
2-3	Position the pole, mix and pour the concrete	1 hour
3-4	Allow time for concrete to set	16 hours (which is 2 days)
4-5	Fit the windsock to the pole	1 hour

No one needs network analysis to realize that this project is going to take a minimum of 2.5 days to complete.

The estimated achievement time for each event (written above the event circle) is calculated by adding up the estimated durations of all the preceding activities from left to right along the arrow path. These event times are the earliest possible times by which the events can be achieved.

Dummy activities The network in Figure 13.3 represents a slightly more complex project (shown here without its activity descriptions). Now the configuration is actually seen to be a network of activities, and not just a simple straight-line sequence. As in all project networks, there is more than one path through the arrows from project start to finish. In this example there are three possible routes to the final event 6, one of which flows through the dummy activity arrow linking event 4 to event 3.

Dummy activities (usually called dummies for short) do not represent actual work and almost always have zero duration. Rather, they denote a constraint or line of dependence between different activities. In Figure 13.3, therefore, the start of activity 3-6 is dependent not only upon completion of activity 2-3, but it must also await completion of activity 1-4. Alternatively expressed, activity 3-6 cannot start until events 3 and 4 have both been achieved.

The arrows for dummy activities are always drawn with dotted or broken lines.

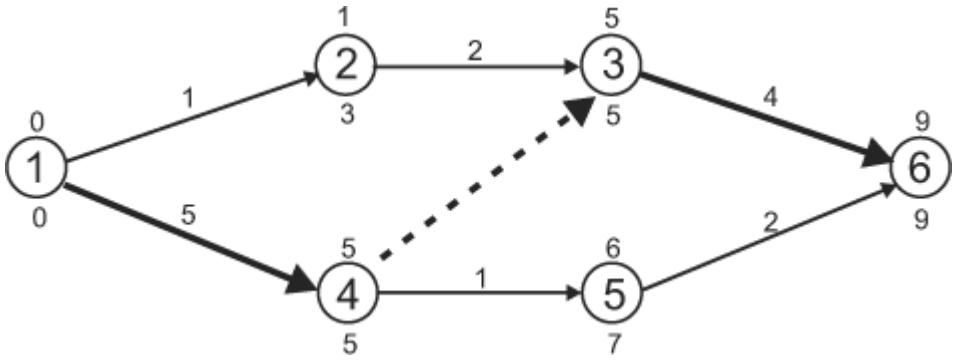


Figure 13.3 An example of arrow network time analysis

The dotted arrow in this network is a dummy activity. A dummy does not represent a real task and usually has zero duration but it acts as a logical link between events. In this simple network, the start of activity 3-6 depends not only on completion of activity 2-3 but (through the dummy) also on completion of activity 1-4. In other words, activities 2-3 and 1-4 must both be finished before event 3 is achieved. The number above each event circle is its earliest possible completion time and the number below is the latest permissible completion time (see text for more details). The longest path through the network is the critical path, shown here in bold arrows. Some networks have more than one equal critical path.

Time Analysis with Arrow Networks

Time units for activity durations In Figure 13.3 (as in the simple windsock project) numbers have been written above the activity arrows to show their estimated durations. Planners should always choose these time units according to their suitability for the project. In the windsock project, hours were the most appropriate unit of time. Days or weeks are most often used in practice for project plans, and we have chosen weeks for this example. The best computer programs will accept any unit of time from minutes to years.

Some computer programs allow different units of time to be mixed in the same project network. For example, Micro Planner X-Pert has a default duration unit format of weeks, days. For example, 1,3 would mean one week and three days total duration. That works well with this particular software but using mixed time units in the same network can lead to some very peculiar results. Messy tabulations are seen when the computer prints out the results—especially when hours are introduced into the mix. Best practice has always been that the planner chooses a suitable unit and uses it consistently throughout the network.

A common choice (and the default option presented by many computer programs) is to choose a working day as the network duration unit, with five such units representing one working week. Thus an activity duration of 1

indicates time occupying one day during normal working hours. A duration estimate of 10 would indicate 2 whole calendar weeks. There is more on the choice of different calendars in Chapter 16.

The forward pass through the network In the tiny project network of Figure 13.3, the earliest possible time for each event and the earliest possible time for project completion at event 6 have been calculated by adding activity duration estimates along the arrows from left to right. This is always the first step in the full-time analysis of any network and is known as the *forward pass*.

The forward pass process is more complicated in this case than it was in the simple windsock project because there is more than one possible path through the network. The earliest time indicated for each event might appear to depend on which path is followed, but can be only one correct result, determined by the longest preceding path. The earliest possible completion time for event 3, for instance might seem to be 1 + 2 = 3, if the path through events 1, 2 and 3 is taken. Event 3 cannot really be achieved, however, until the end of week 5 because of the longer path through the dummy. This also means that the earliest possible start time for activity 3-6 is the end of week 5 (or, for more practical purposes, the beginning of week 6).

Thus the earliest possible time for any event is found by adding the estimated durations of all preceding activities along the path that produces the greatest time. By following this procedure through the network to the end of the project at event 6 it emerges that the earliest possible project completion time is estimated as nine weeks.

The backward pass Now consider event 5 in Figure 13.3. Its earliest possible achievement time is the end of week 6, three weeks before the earliest possible time for finishing the project at event 6. It is clear that activity 5-6, which is only expected to last for two weeks, could be delayed for up to one week without upsetting the overall timescale. In other words, although the earliest possible achievement time for event 5 is week 6, its latest permissible achievement time is the end of week 7. This result can be indicated on the arrow diagram by writing the latest permissible time underneath the event circle. The result is found this time, not by addition from left to right along the arrows, but in exactly the opposite way by subtracting the estimated durations of activities from right to left (9 - 2 = 7 for event 5).

This subtraction exercise can be repeated throughout the network, writing the latest permissible times below all the event circles. Where more than one path exists, the longest must always be chosen so that the result after subtraction gives the smallest remainder. This is illustrated at event 4 in Figure 13.3, where the correct subtraction route lies through the dummy.

Float or slack The term 'float' indicates the amount of leeway available for achieving an event (the difference between its earliest possible and latest permissible times) without jeopardizing the earliest possible completion time for the whole project. The amount of float at an event also determines the leeway available for starting and finishing activities that pass through the event. Strictly speaking, 'float' is the correct word for the leeway of activities (as opposed to 'slack' for events). However, those distinctions have been lost with the passing of time so that slack and float are now used synonymously. There are various categories of float but we shall delay the explanation of those until Chapter 15, because one particular significance of float is the effect that it has on allocating resources to activities.

The critical path When all the earliest possible and latest permissible times have been added to the diagram there will be at least one chain of events from the start of the network to the end where the earliest and latest event times are the same, indicating zero float. These events are critical to the successful achievement of the whole project within its earliest possible time. The route joining these events is not surprisingly termed the *critical path.* Although all activities may be important, it is those that lie on the critical path that must claim priority for management attention and the supply of scarce resources.

It is always possible that two or more different paths through a network will have the same total duration, so that there might be more than one critical path.

THE 4J AIRSTRIP PROJECT PLANNED USING AN ARROW NETWORK DIAGRAM

Figure 13.4 shows how the 4J airstrip project might look if it were to be planned as an arrow critical path network diagram. This schedule is approximately equivalent to the Gantt chart that was shown in Figure 12.3. At

first sight this arrow diagram suddenly looks very complicated when compared with the three earlier examples in this chapter, but it is only a multiple combination of the notational elements already described. Excluding dummies, this network has only 45 activities, and every aviation project would have at least ten times as many as that. However, our case example is adequate for demonstrating the method with clarity within the space available in our book pages.

Note particularly how dummy activities have been used here. These serve two principal purposes, which are:

- To ensure that the logic is correct and what the planner intended. For example, at event 15 the planner has extended a dummy to event 20, indicating that the sink and its drain (activity 20-31) cannot be installed in the hangar until the barn-to-hangar conversion has been finished.
- To give two or more parallel activities separate identities. There are two examples of this in Figure 13.4. Look, for instance, at event 3. The addition of dummy 3-4 does not affect the logic but without it both activities 'order fencing' and 'fell trees' would be numbered exactly the same as activity 2-3. They would be seen by the computer as duplicated activities, which can never be allowed. The other example of this in Figure 13.4 is at event 21.

Time analysis of a small network such as this is easy mentally, provided that the results are expressed only as day numbers and not required as calendar dates. But day numbers are practically useless for the project manager, and so they must be converted to calendar dates. Remember that Jill had to replan and restart this project after the four farmers had effectively achieved zero progress, and so day 1 for her (the new project start date) must be 1 August 2011, A computer is practically essential to convert the day numbers into calendar dates, and it is able to remove holidays and other non-working days from the available time.

We used Micro Planner X-Pert to process the network analysis data for the 4J airstrip project. This program (which can accept either arrow diagrams or precedence diagrams) has a wide range of capabilities that include cost and resource scheduling. It has a range of report formats that can help the project manager to plan and manage a project. Although training in any project management software is always to be advised in order to benefit

from its capabilities, we found this software easy to use and were able to obtain all the data that we needed for this chapter.

Printed reports from project management software often require large areas of paper, so neither the network analysis plot nor the useful Gantt chart produced by Micro Planner X-Pert are shown here, but both were well plotted and easy to follow by scrolling them on the computer screen.

We have condensed the time analysis results calculated by Micro Planner X-Pert for the 4J airstrip project into a smaller space in Figure 13.5, but the data are all exactly as reported by the program. We followed the usual convention by excluding dummies. This time analysis report was calculated before any work on the project had started. Had the project been in progress, an updated report would have started from a new time datum (always known as 'time-now' in these applications) and completed activities could have been omitted.

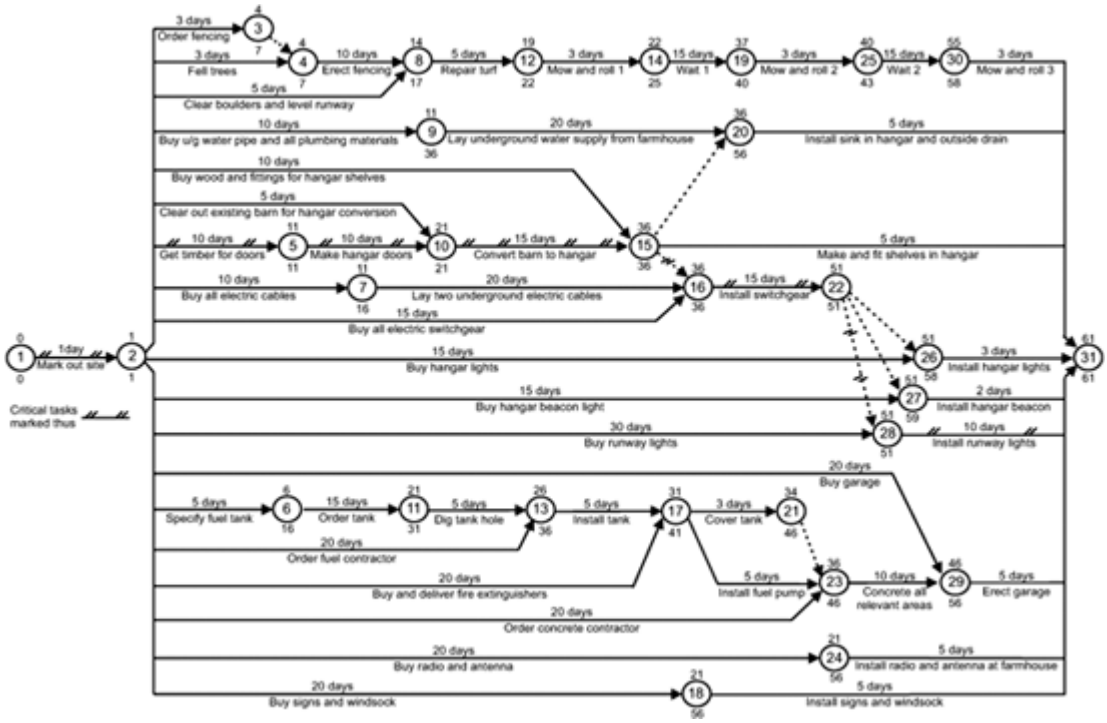


Figure 13.4 Activity-on-arrow critical path network diagram for the 4J airstrip project

ID	Description	Duration	Float	EARLY		LATE	
				Start	Finish	Start	Finish
1 - 2	Mark out site	0,1	0,0	1-Aug-11	1-Aug-11	1-Aug-11	1-Aug-11
2 - 3	Order fencing	0,3	0,3	2-Aug-11	4-Aug-11	5-Aug-11	9-Aug-11
2 -4	Fell trees	0.3	0,3	2-Aug-11	4-Aug-11	5-Aug-11	9-Aug-11
2 - 6	Specify fuel tank	1,0	2.0	2-Aug-11	8-Aug-11	16-Aug-11	22-Aug-11
2 - 8	Clear boulders and level runway	1,0	2,1	2-Aug-11	8-Aug-11	17-Aug-11	23-Aug-11
2 - 10	Clear out barn	1,0	3,0	2-Aug-11	8-Aug-11	23-Aug-11	29-Aug-11
2 - 5	Get timber for doors	2,0	0,0	2-Aug-11	15-Aug-11	2-Aug-11	15-Aug-11
2 - 7	Buy electric cables	2,0	1,0	2-Aug-11	15-Aug-11	9-Aug-11	22-Aug-11
2 - 9	Buy u/g water pipe and plumbing materials	2,0	5,0	2-Aug-11	15-Aug-11	6-Sep-11	19-Sep-11
2 - 15	Buy wood and fittings for hangar shelves	2,0	5,0	2-Aug-11	15-Aug-11	6-Sep-11	19-Sep-11
2 - 28	Buy runway lights	6,0	4,0	2-Aug-11	12-Sep-11	30-Aug-11	10-Oct-11
2 - 26	Buy hangar lights	3,0	8,2	2-Aug-11	22-Aug-11	29-Sep-11	19-Oct-11
2 - 27	Buy beacon light	3,0	8,2	2-Aug-11	22-Sep-11	29-Sep-11	19-Oct-11
2 - 13	Order fuel contractor	4,0	3,0	2-Aug-11	29-Aug-11	23-Aug-11	19-Sep-11
2 - 17	Buy and deliver fire extinguishers	4,0	4,0	2-Aug-11	29-Aug-11	30-Aug-11	26-Sep-11
2 - 23	Order concrete contractor	4,0	5,0	2-Aug-11	29-Aug-11	6-Sep-11	3-Oct-11
2 - 18	Buy signs and windsock	4,0	7,0	2-Aug-11	29-Aug-11	20-Sep-11	17-Oct-11
2 - 24	Buy radio and antenna	4,0	7,0	2-Aug-11	29-Aug-11	20-Sep-11	17-Oct-11
2 - 29	Buy garage	4,0	7,0	2-Aug-11	29-Aug-11	20-Sep-11	17-Oct-11
4 - 8	Erect fencing	2,0	0,3	5-Aug-11	18-Aug-11	10-Aug-11	23-Aug-11
6 - 11	Order tank	3,0	2,0	9-Aug-11	29-Aug-11	23-Aug-11	12-Sep-11
5 - 10	Make hangar doors	2,0	0,0	16-Aug-11	29-Aug-11	16-Aug-11	29-Aug-11
7 -16	Lay two underground electric cables	4,0	1,0	16-Aug-11	12-Sep-11	23-Aug-11	19-Sep-11
9 - 20	Lay u/g water supply from farmhouse	4,0	5,0	16-Aug-11	12-Sep-11	20-Sep-11	17-Oct-11
8 - 12	Repair turf	1,0	0,3	19-Aug-11	25-Aug-11	24-Aug-11	30-Aug-11
12 - 14	Mow and roll 1	0,3	0,3	26-Aug-11	30-Aug-11	31-Aug-11	2-Sep-11
11 -13	Dig tank hole	1,0	2,0	30-Aug-11	5-Sep-11	13-Sep-11	19-Sep-11
18 - 31	install signs and windsock	1,0	7,0	30-Aug-11	5-Sep-11	18-Oct-11	24-Oct-11
24 - 31	Install radio and antenna at farmhouse	1,0	7,0	30-Aug-11	5-Sep-11	18-Oct-11	24-Oct-11
10 - 15	Convert barn to hangar	3,0	0,0	30-Aug-11	19-Sep-11	30-Aug-11	19-Sep-11
14 - 19	Wait 1	3,0	0,3	31-Aug-11	20-Sep-11	5-Sep-11	23-Sep-11
13 - 17	Install tank	1,0	2,0	6-Sep-11	12-Sep-11	20-Sep-11	26-Sep-11
17 - 21	Cover tank	0,3	2,2	13-Sep-11	15-Sep-11	29-Sep-11	3-Oct-11
17 - 23	Install fuel pump	1,0	2,0	13-Sep-11	19-Sep-11	27-Sep-11	3-Oct-11
15 - 31	Make and fit shelves in hangar	1,0	4,0	20-Sep-11	26-Sep-11	18-Oct-11	24-Oct-11
20 - 31	Install sink and outside drain at hangar	1,0	4,0	20-Sep-11	26-Sep-11	18-Oct-11	24-Oct-11
23 - 29	Concrete all relevant areas	2,0	2,0	20-Sep-11	3-Oct-11	4-Oct-11	17-Oct-11
16 - 22	Install switchgear	3,0	0,0	20-Sep-11	10-Oct-11	20-Sep-11	10-Oct-11
19 - 25	Mow and roll 2	0,3	0,3	21-Sep-11	23-Sep-11	26-Sep-11	28-Sep-11
25 - 30	Wait 2	3,0	0,3	26-Sep-11	14-Oct-11	29-Sep-11	19-Oct-11
29 - 31	Erect garage	1,0	2,0	4-Oct-11	10-Oct-11	18-Oct-11	24-Oct-11
26 - 31	install hangar lights	0,3	1,2	11-Oct-11	13-Oct-11	20-Oct-11	24-Oct-11
27 - 31	Install hangar beacon	0,3	1,2	11-Oct-11	13-Oct-11	20-Oct-11	24-Oct-11
28 - 31	Install runway lights	2,0	0,0	11-Oct-11	24-Oct-11	11-Oct-11	24-Oct-11
30 - 31	Mow and roll 3	0,3	0,3	17-Oct-11	19-Oct-11	20-Oct-11	24-Oct-11

Note: All the time units in this schedule are given in the format weeks,days. Thus, for example, 0,1 represents 1 day and 3,1 would be 3 weeks and 1 day. The default calendar of 5 working days per week applies throughout.

Figure 13.5 Time analysis of the 4J airstrip project

This schedule was calculated using Micro Planner X-Pert. Tasks are sorted in ascending order of their earliest start dates.

Results for the 4J airstrip project The activities shown in Figure 13.5 are listed in ascending order of their earliest possible start dates. Most project managers find that sort sequence useful for allocating tasks to people and for checking day-by-day progress. This sort sequence is the reason why the ID codes in this tabulation appear to be listed in random order.

We could have taken scheduling much farther with this software to include resource scheduling and cost reports (subjects dealt with in later chapters). However, Jill now has a far more practicable and detailed plan than the original lists made in the farmers' diaries. Now she can issue work reminders and monitor progress on a daily basis. Jill knows from the time analysis report that the earliest date when this project could finish is 24 October 2011 and that the critical path runs through the activities shown with zero float. The plots generated by Micro Planner X-Pert show all those critical activities highlighted in bright red in both the network and Gantt chart views.

Small projects are often managed successfully from the kind of time analysis schedule shown here in Figure 13.5 without exploiting the more advanced capabilities of the software.

Use of alternative calendars The sharper-eyed readers will have spotted by that this airstrip has now been planned on the basis of a five-day week with no work done at weekends, whereas the four farmers all have other day jobs. Thus, please assume the purposes of this exercise that the heavy work on the farms will be done by family members and farm workers, with the farm (and project) owners acting in an advisory management role. If we had decided to allow some jobs to carry through weekends, or indeed be performed only at weekends, we would simply have specified different calendars in the software files, and allocated the appropriate calendar for each activity. For example, we could have specified a calendar that allowed working only on Saturdays, called it 'Calendar 2', and assigned 'Calendar 2' in place of the default calendar to the relevant Saturday tasks.

We wished to keep things simple at this stage in the description of the critical path method, but alternative calendars are indeed very valuable for projects that mix shift working with day working, or where international borders are spanned and work in some countries is subject to different working days and holidays from others. We shall explain more about the use of different calendars Chapter 16.

ACTIVITY-ON-NODE (PRECEDENCE) NETWORK DIAGRAMS

The precedence system of notation is preferred by many and has emerged as the dominant method for the following reasons:

- Precedence logic diagrams more closely resemble engineering flow diagrams or block schematic diagrams than arrow diagrams and are therefore more easily understood by people with no training in the use or understanding of critical path network diagrams.
- Precedence notation allows clear illustration of activities whose starts and finishes do not coincide directly with the starts and finishes of their immediate predecessors and successors. In other words, precedence networks can show activities that can be allowed to overlap each other or which, conversely, must be separated by a time delay.
- Precedence networks are widely supported by computer software.
- As with arrow diagrams, precedence networks cannot be used to schedule resources without either conversion into Gantt chart form (for tiny projects) or the use of a computer.

Activities in precedence diagrams Figure 13.6 shows the convention for an activity in precedence notation. Although this must be the preferred pattern when networks are drawn by hand, it is an ideal not achieved when networks are plotted by computer because the software will limit the amount of data that can be included in each activity box. Without such limitation networks would take up far too much screen space and would need even larger areas of paper for a complete network than they do at present.

Direction The flow of work in a precedence diagram is (as for arrow diagrams) always from left to right.

Scale Precedence diagrams are not drawn to scale. Neither the lengths of the links nor the sizes of activity boxes have no significance whatsoever.

Activity identifiers Every activity is given a unique identification number, usually referred to as its *ID code*. These codes are necessary for computer processing. Activity identification is a little simpler in precedence networks

than it is in their arrow equivalents because it is not necessary to specify a preceding event code and a succeeding event code. A single code for each activity is all that is required. These ID codes can range from small serial numbers to complex alphanumeric codes, depending on the size and complexity of the network, the planner's requirements and the capacity of the computer software for accommodating long ID numbers.

Logical dependencies and constraints All the activities comprising a project are linked by lines which, unlike the arrows in arrow diagrams, almost always have zero duration.

Precedence notation allows more freedom to express complex inter-activity relationships than the arrow diagram method. Activities can, for example, be shown to overlap rather than follow each other in strict sequence. Complex links are described later in Chapter 14. Their use can be valuable, but they are far less common than simple finish-start links. Although most project management computer programs allow complex links, they usually assume finish-start relationships with zero link duration by default.

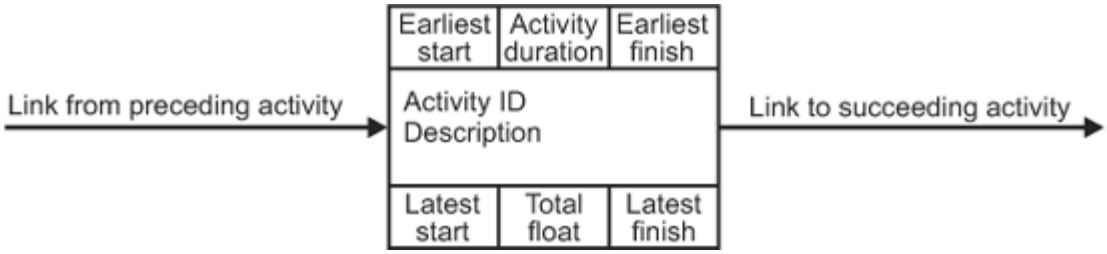


Figure 13.6 The ideal way of representing an activity in precedence notation

Activity duration estimates and descriptions The simple windsock project, which was shown as four sequential arrow activities in Figure 13.2, translates easily into the precedence diagram shown in Figure 13.7. The activity duration estimates for this very simple project are repeated below:

Activity	*Description*	*Estimated duration*
1	Dig the hole	2 hours
2	Position the pole, mix and pour the concrete	1 hour
3	Allow time for concrete to set	16 hours (which is 2 days)
4	Fit the windsock to the pole	1 hour

The earliest estimated start and finish times for these activities, found by adding up the estimated durations from left to right, have been written in the activity boxes. Although hours were used in this simple case, days or weeks are the more customarily used project time units in aviation projects.

Time Analysis with Precedence Networks

Figure 13.8 is a very simple precedence network (the equivalent of the arrow network in Figure 13.3). The identifier codes placed in brackets show how these precedence activities correspond with those in the arrow network version. All duration estimates are in weeks for this example.

The start and finish activities are not strictly necessary, and have no corresponding activities in the arrow diagram equivalent. They have been introduced here because it is always desirable to start and finish a network at single nodes (as explained in the previous section).

The forward pass In the project network of Figure 13.8, the earliest overall project duration possible has been calculated by adding activity duration estimates through the links, passing from left to right. There is more than one possible path through the network and the path with the longest duration will determine the earliest possible finish time for this project.

The earliest possible start time for activity 4 might seem to be 0 + 1 + 2 = 3 (the end of week 3) if the path through activities 1, 2 and 3 is taken. However activity 4 cannot start until the end of week 5 (which in practice means the beginning of week 6) because it is constrained by the longer path through activities 1 and 5.

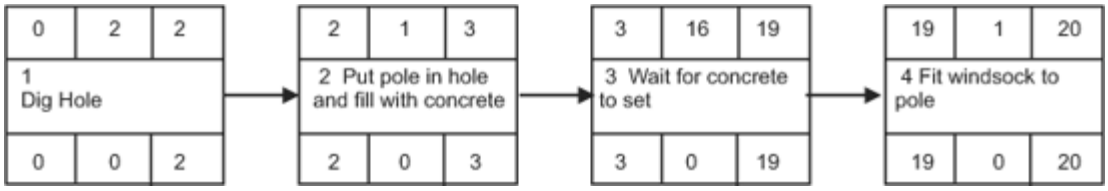


Figure 13.7 The windsock project using precedence network notation
This is the windsock project network shown in Figure 13.2, now redrawn as a precedence network.

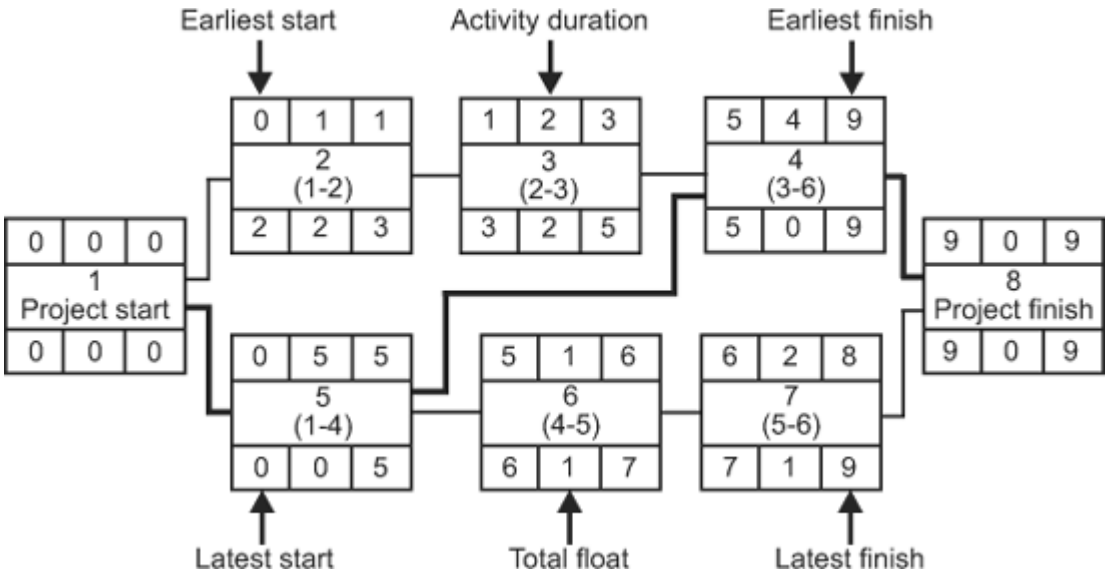


Figure 13.8 An example of precedence network time analysis
The critical path is shown by the bold links. Activity ID numbers in brackets denote the corresponding activities in the arrow version of this network, shown in Figure 13.3.

By following this procedure through the network to the end of the project at activity 8 it emerges that the earliest possible estimated project duration is nine weeks (with completion at the end of the week 9).

The backward pass Now consider activity 7 in Figure 13.8. Its earliest possible finish time is the end of week 8, one week before the earliest possible time for finishing the project at the end of week 9 (activity 8). It is clear that activity 7 could be delayed for up to one week without upsetting the overall timescale and delaying the project. This possible delay can be expressed as a total float of one week, entered in the centre bottom box of the activity. This result is also indicated on the activity box by writing the latest permissible finish time in its bottom right-hand corner. The result is found this time, not by addition from left to right through the network, but in exactly the opposite way of subtraction from right to left. So the latest permissible start for activity 7 is seen to be (9 - 2) = 7 (meaning the end of week 7 or the beginning of week 8).

This subtraction exercise must be repeated throughout the network, working backwards from right to left, writing the latest permissible times and floats along the bottom rows of all the activity boxes. Where more than one path exists, the longest must always be chosen so that the result after subtraction gives the smallest remainder (earliest time). This is illustrated in

Figure 13.8 at activity 5, for instance, where the correct subtraction route lies through the activities 8 and 4.

Float or slack The term 'float' indicates the amount of leeway available for starting and finishing an activity if the project finish time is not to be delayed. The subtle differences between the terms 'float' and 'slack' have been lost over the years and the two terms are now synonymous. There are various categories of float. These are explained in Chapter 16, in the context of deciding priorities during resource scheduling, but they can be ignored for the purposes of this simple example.

The critical path When all the earliest possible and latest permissible times have been added to the diagram, there will always be at least one chain of activities where the earliest and latest times coincide, indicating zero float. These activities are critical to the successful achievement of the whole project within its earliest possible time and the route following these activities through the network is called the *critical path.*

Although all activities may be important to successful project conclusion, it is the critical activities that must claim priority for scarce resources and for management attention.

THE 4J AIRSTRIP PROJECT PLANNED USING A PRECEDENCE DIAGRAM

In Chapter 12 we described a fictional project to build a private airstrip on farmland and earlier in this chapter we showed how it might have been planned using an activity-on-arrow critical path diagram (Figure 13.4). The precedence equivalent of this network plan is shown in Figure 13.9. The logic for these two networks is identical in all important respects. We did allow one insignificant logical difference between these two networks to keep things as simple as possible, but this did not affect the schedule. If any keen student wishes to search for this difference we suggest that they should look in the area of the fire extinguishers.

The precedence version of this plan clearly takes up more space than its arrow equivalent and it was also more time consuming to draw. However it does display the logic of the project very clearly and, once you are familiar

with the notation, you will find that far more time analysis information can provided for each activity on the network diagram.

Whereas we ran the arrow version using Micro Planner X-Pert, for this precedence diagram we chose to use Microsoft Project, simply to allow comparison and add variety. As with most project management software the graphic reports were too big to reproduce unedited in these pages. However, with Microsoft Project the activity data appear in columns at the left-hand side of the Gantt chart view. The user is able to choose which data to include in this tabulation by adding columns from a very comprehensive browser. We chose to include only the time analysis data and that (after cropping off the Gantt chart bars) we reproduce in Figure 13.10. Comparison with Figure 13.5 shows that, as one would expect and hope, the times calculated by Microsoft Project are almost identical with those produced by Micro Planner X-Pert from the arrow diagram.

Once again we have chosen to sort the activities in ascending order of their earliest start dates. For project control where no resource scheduling has been carried out this is probably the most useful sort sequence. One exception would be for an expeditor working in a purchasing organization. For that person, the latest finish times of all the activities connected with deliveries of goods are most important and then a sort by latest finish dates might be more useful.

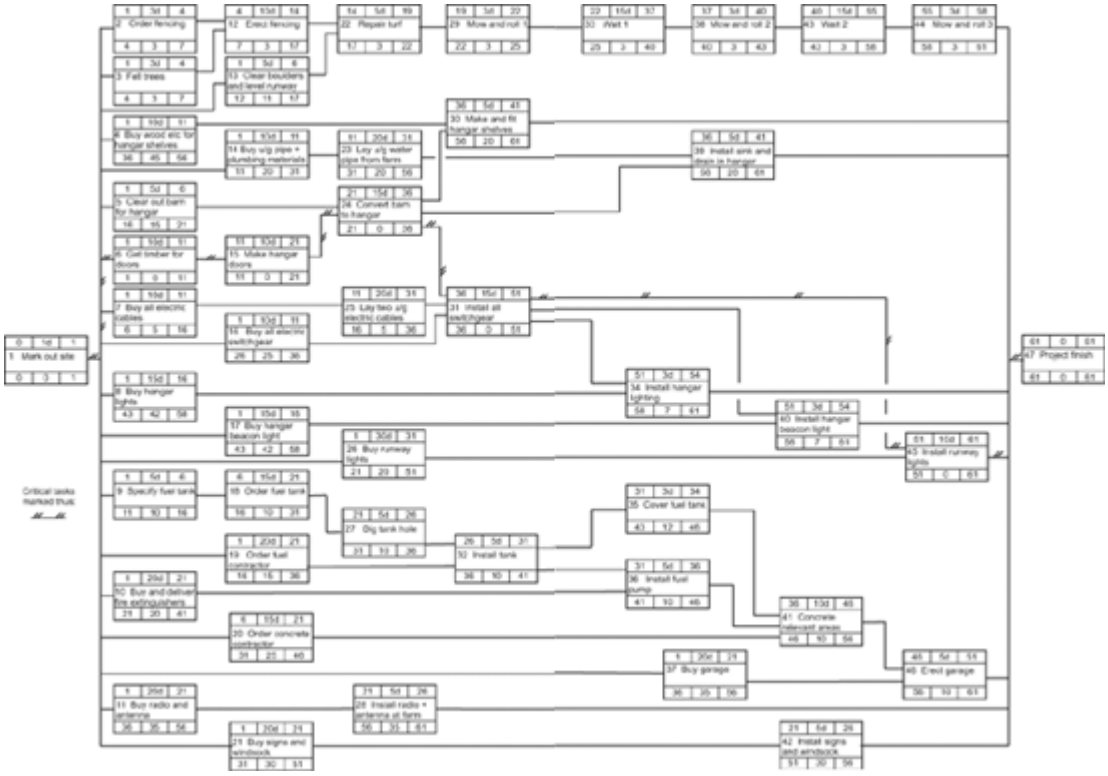


Figure 13.9 Precedence network diagram of the 4J airstrip project

	Task Name	ID	Duration	Early Start	Early Finish	Late Start	Late Finish	Free Slack	Total Slack
	Mark out site	1	1 day	01 Aug '11	01 Aug '11	01 Aug '11	01 Aug '11	0 days	0 days
	Order fencing	2	3 days	02 Aug '11	04 Aug '11	05 Aug '11	09 Aug '11	0 days	3 days
	Fell trees	3	3 days	02 Aug '11	04 Aug '11	05 Aug '11	09 Aug '11	0 days	3 days
	Buy wood for shelves	4	10 days	02 Aug '11	15 Aug '11	16 Aug '11	29 Aug '11	10 days	10 days
	Clear out barn for hangar	5	5 days	02 Aug '11	08 Aug '11	23 Aug '11	29 Aug '11	15 days	15 days
	Get timber for doors	6	10 days	02 Aug '11	15 Aug '11	02 Aug '11	15 Aug '11	0 days	0 days
	Buy all electric cables	7	10 days	02 Aug '11	15 Aug '11	16 Aug '11	29 Aug '11	10 days	10 days
	Buy hangar lights	8	15 days	02 Aug '11	22 Aug '11	09 Aug '11	29 Aug '11	5 days	5 days
	Specify fuel tank	9	5 days	02 Aug '11	08 Aug '11	23 Aug '11	29 Aug '11	0 days	15 days
	Buy and deliver fire extinguishers	10	20 days	02 Aug '11	29 Aug '11	06 Sep '11	03 Oct '11	10 days	25 days
	Buy radio and antenna	11	20 days	02 Aug '11	29 Aug '11	23 Aug '11	19 Sep '11	0 days	15 days
	Clear boulders, level runway	13	5 days	02 Aug '11	08 Aug '11	23 Aug '11	29 Aug '11	15 days	15 days
	Buy u/g pipe and plumbing materials	14	10 days	02 Aug '11	15 Aug '11	16 Aug '11	29 Aug '11	0 days	10 days
	Buy electric switchgear	16	10 days	02 Aug '11	15 Aug '11	16 Aug '11	29 Aug '11	10 days	10 days
	Buy hangar beacon light	17	15 days	02 Aug '11	22 Aug '11	09 Aug '11	29 Aug '11	5 days	5 days
	Order fuel contractor	19	20 days	02 Aug '11	29 Aug '11	30 Aug '11	26 Sep '11	5 days	20 days
	Order concrete contractor	20	15 days	02 Aug '11	22 Aug '11	20 Sep '11	10 Oct '11	20 days	35 days
	Buy signs and windsock	21	20 days	02 Aug '11	29 Aug '11	20 Sep '11	17 Oct '11	0 days	35 days
	Buy runway lights	26	30 days	02 Aug '11	12 Sep '11	16 Aug '11	26 Sep '11	10 days	10 days
	Buy garage	37	20 days	02 Aug '11	29 Aug '11	20 Sep '11	17 Oct '11	0 days	35 days
	Erect fencing	12	10 days	05 Aug '11	18 Aug '11	10 Aug '11	23 Aug '11	0 days	3 days
	Order fuel tank	18	15 days	09 Aug '11	29 Aug '11	30 Aug '11	19 Sep '11	0 days	15 days
	Make hangar doors	15	10 days	16 Aug '11	29 Aug '11	16 Aug '11	29 Aug '11	0 days	0 days
	Lay u/g water pipe	23	20 days	16 Aug '11	12 Sep '11	30 Aug '11	26 Sep '11	10 days	10 days
	Lay 2 u/g cables	25	20 days	16 Aug '11	12 Sep '11	30 Aug '11	26 Sep '11	10 days	10 days
	Repair turf	22	5 days	19 Aug '11	25 Aug '11	24 Aug '11	30 Aug '11	0 days	3 days
	Mow and roll 1	29	3 days	26 Aug '11	30 Aug '11	31 Aug '11	02 Sep '11	0 days	3 days

Convert barn to hangar	24	15 days	30 Aug '11	19 Sep '11	30 Aug '11	19 Sep '11	0 days	0 days
Dig tank hole	27	5 days	30 Aug '11	05 Sep '11	20 Sep '11	26 Sep '11	15 days	15 days
Install radio at farm	28	5 days	30 Aug '11	05 Sep '11	20 Sep '11	26 Sep '11	15 days	15 days
Install signs and windsock	42	5 days	30 Aug '11	05 Sep '11	18 Oct '11	24 Oct '11	35 days	35 days
Wait 1	33	15 days	31 Aug '11	20 Sep '11	05 Sep '11	23 Sep '11	0 days	3 days
Install tank	32	5 days	06 Sep '11	12 Sep '11	27 Sep '11	03 Oct '11	0 days	15 days
Cover fuel tank	35	3 days	13 Sep '11	15 Sep '11	06 Oct '11	10 Oct '11	2 days	17 days
Install fuel pump	36	5 days	13 Sep '11	19 Sep '11	04 Oct '11	10 Oct '11	0 days	15 days
Make and fit shelves	30	5 days	20 Sep '11	26 Sep '11	07 Oct '11	13 Oct '11	13 days	13 days
Install switchgear	31	15 days	20 Sep '11	10 Oct '11	20 Sep '11	10 Oct '11	0 days	0 days
Install sink and drain	39	5 days	20 Sep '11	26 Sep '11	07 Oct '11	13 Oct '11	13 days	13 days
Concrete relevant areas	41	10 days	20 Sep '11	03 Oct '11	11 Oct '11	24 Oct '11	15 days	15 days
Mow and roll 2	38	3 days	21 Sep '11	23 Sep '11	26 Sep '11	28 Sep '11	0 days	3 days
Wait 2	43	15 days	26 Sep '11	14 Oct '11	29 Sep '11	19 Oct '11	0 days	3 days
Erect garage	46	5 days	30 Aug '11	05 Sep '11	18 Oct '11	24 Oct '11	35 days	35 days
Install hangar lighting	34	3 days	11 Oct '11	13 Oct '11	20 Oct '11	24 Oct '11	7 days	7 days
Install hangar beacon light	40	3 days	11 Oct '11	13 Oct '11	20 Oct '11	24 Oct '11	7 days	7 days
Install runway lights	45	10 days	11 Oct '11	24 Oct '11	11 Oct '11	24 Oct '11	0 days	0 days
Mow and roll 3	44	3 days	17 Oct '11	19 Oct '11	20 Oct '11	24 Oct '11	3 days	3 days
Project finish	47	0 days	24 Oct '11	24 Oct '11	24 Oct '11	24 Oct '11	0 days	0 days

Project: 4J airstrip
Date: 02 Dec '08

Task — Milestone — External Tasks
Split — Summary — External Milestone
Progress — Project Summary — Deadline

Figure 13.10 Time analysis of the 4J airstrip project processed and reported by Microsoft Project

DUMMY ACTIVITIES IN PRECEDENCE NETWORKS

A dummy activity is an activity requiring no work and signifying no actual activity or duration. Therefore all the links in precedence networks could possibly be regarded as dummies, because they incur no effort or expense and (almost always) no time. But these links are never called dummies and it is true to say in general that dummy activities do not occur in precedence networks as they do in their arrow diagram counterparts. However, we can introduce activities with zero duration in precedence diagrams to clarify or improve the logic diagram, and then we really have added activities that resemble dummies (discussed further below, see Figure 13.11).

Use of Zero Duration Activities To Prevent Dangling Activities

It is always best practice to start any network (arrow or precedence) at a single node. In networks where several activities can all begin as soon as the project is authorized, if those activities are not drawn to emerge from a single node the computer will detect more than one project start in the logic and it will report those separate starts as dangles because they have no

predecessors. Every perfect network should have only one start dangle and one finish dangle, because they provide the start and finish reference points for all time analysis calculations (in other words, they allow all paths through the network to begin at the project beginning and end at the project end).

All the network diagrams shown in this book obey this single start and single finish rule. In the precedence network shown in Figure 13.9 the site mark-out activity provided a convenient, logically correct start activity and there are thus no start dangles. The finish of that project is, however, a very different story so it was necessary to add the zero duration project finish activity (a dummy, if you like) as activity 47, with zero duration. Now the computer is able to follow each path through to the logical end of the project and calculate time analysis. Without activity 47, time analysis could not have been performed correctly because every path would end in a dangle unconnected to the latest permissible time for completing the whole project.

Use of Dummies in Precedence Networks to Clarify The Logic Diagram

Expert planners always do their best when drawing network diagrams to lay out the various activities and paths so that crossovers are avoided as far as possible. A network with too many crossovers is very difficult even for the experienced planner to interpret and check.

There are occasions in precedence diagrams where an additional node can be inserted that has no logical significance and no duration, but which can greatly clarify the logic for the human eye. Artificial activities added for this purpose have zero duration and absolutely no work significance. They are merely instruments of convenience, and are thus dummies. We give an example where the addition of dummies can greatly improve network clarity in Figure 13.11.

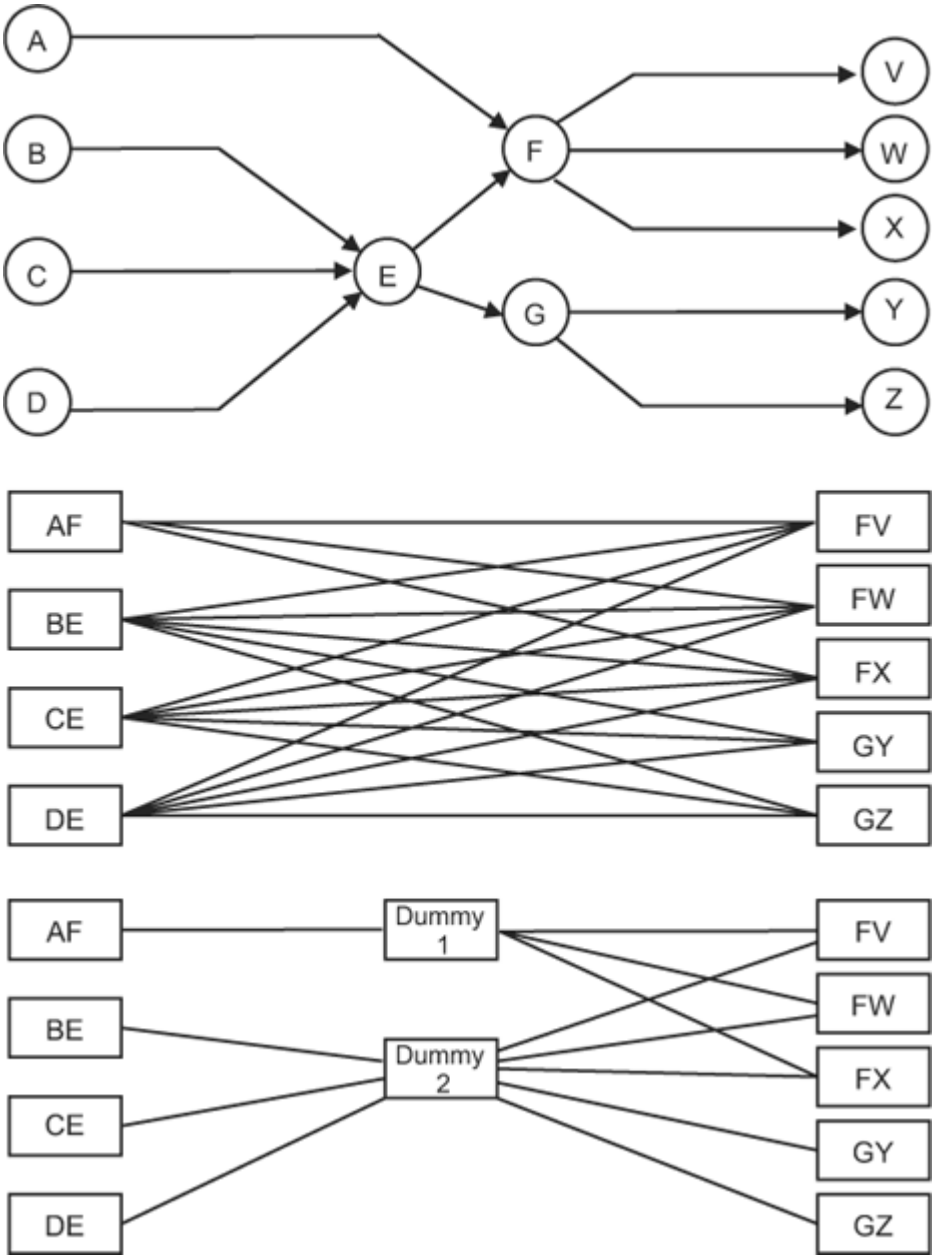


Figure 13.11 Use of dummies in precedence notation to clarify the logic
The logic of the arrow diagram and both precedence diagrams is identical but note how the addition of two dummies has clarified the presentation in the bottom version.

REFERENCES

Morris, P., (1994), *The Management of Projects*, London, Thomas Telford.

14
Critical Path Network Analysis in More Practical Detail

The previous chapter explained the concept and basic theory of critical path analysis. Both the arrow and precedence network methods were introduced and illustrated using a case example. This chapter begins by examining some of the more practical, 'hands on' aspects of constructing a plan for a new project. We shall then explain some variants or slightly more advanced applications of critical path network analysis, again illustrated with case examples.

MAKING A DETAILED PLAN FOR A NEW PROJECT

It should be apparent that an overall project network diagram and schedule can engender a number of sub-plans. This is particularly true for many aviation projects, where major sub-contractors or partners will carry out substantial parts of the project in separate premises, using plant, equipment and staff that are not directly employed or controlled by the main contractor. Every one of these partners and sub-contractors will need to make their own detailed plans to fit within an overall planning framework determined by the main contractor. So we need to be clear that the first project planning meeting, which is the subject of this chapter section, often sets out to produce a master network diagram and project schedule into which all the partners and sub-contractors must subsequently fit their own detailed plans.

The First Planning Meeting: Who Should be There?

Every project working plan should enshrine a consensus of the ideas and commitments of those who will have to manage work on the project. This implies that the initial critical path network should be sketched at a meeting

where the planner can obtain the best possible advice on what tasks need to be included, how they should be sequenced, what resources they will need and how long the responsible manager or engineer expects that each task will take.

The first planning meeting for a new project is a very important occasion because it maps out the detailed day-to-day work strategy for the project, if not for the remainder of its life, then at least for years or many months into the future. If significant errors or omissions are made now, subsequent correction might be difficult, time consuming, demoralizing and expensive. So, 'right first time' must be the aim. It follows that the first meeting has to be treated as an important occasion, not to be rushed and not to be missed by any of the key people who should be there.

Departmental managers and other senior staff who will subsequently be expected to accept responsibility for fulfilling project tasks adequately, on time and within budget should all be at the first meeting. It is only fair that people who will be expected to commit themselves and their staff to the plan should be invited to the meeting where those commitments are decided. They must be part of the decision-making process.

Where substantial parts of the project are to be sub-contracted, the planning meeting must either be in possession of delivery estimates or promises from each sub-contractor or be in a position to obtain them. Otherwise it would clearly be impossible to determine the overall project time frame or carry out time analysis. Similarly, lead-times for purchases must be known (usually based on experience of past projects, or by input from the purchasing department, or better still from advance quotations).

It is apparent that a planning meeting for a large project can involve more than a small handful of people. Further, the duration of such meetings can often be extended, even beyond a whole day. However, that will be time and money well spent if the project is thus set on its most appropriate course, and when all the senior participants feel that they have played their own part in directing the future tasks.

The First Planning Meeting: Who Should be in Charge?

A planning meeting should be led by a planning expert, a technician who is thoroughly familiar with the planning methods used, who has a gift for logical reasoning, and who can take the thoughts and decisions of those present and

build them into the developing network sketch. This is notwithstanding the fact that the planner might well be junior in rank to other people present. If the organization includes a project support office, the planner might be chosen from its staff. An experienced planner will help to avoid logical errors and omissions in the plan by asking questions such as:

- Can these spars really be fitted immediately after manufacture or would they not need to be anodized first?
- Do we have to wait for this design task to end completely before we can issue purchase orders for the long-lead items? (Some externally manufactured components might take many months to get).
- Would these drawings not have to be checked before issue for manufacture?
- We did it that way on the last project and it was a disaster. Can we think of an alternative?
- Would we not have to have an approval stage in here before this next task can begin?
- Would we not have to recruit a pilot before we could make this first test flight?
- If you have a vibration testing task here, do we not need one or more preceding tasks to design and make the vibration testing clamps or jig?
- OK, we have a wind tunnel test scheduled here but we don't have a wind tunnel. Surely we need to add a task to locate and reserve this test facility from someone who does have a wind tunnel?

It is surprising how many such apparently obvious mistakes a competent planner can prevent, given suitable experience in planning similar past projects.

One very important person at the planning meeting will of course be the project manager, who must oversee the proceedings and ensure that everything that needs to be planned does, in fact, get planned. If the expert planning technician is 'in the chair' (probably from a standing position), perhaps the project manager could be regarded as the meeting's president. The project manager should be the person who best knows the project specification and must be the final arbiter as questions of working strategy are debated and decided.

Practical Planning Hints

Planning meetings should never be held up whilst the planner takes time to draw or redraw the first sketch. The planning methodology itself must not get in the way of the planning strategy.

Highly experienced planners usually find that an arrow network diagram is easier and quicker to draw at this early stage. It can easily be converted to a precedence diagram after the meeting, when the planner has more time. We both favor this approach but this is a matter for personal choice and we know that others will disagree with our view.

The planner will need a small collection of pre-sharpened HB pencils, an eraser, a stencil for drawing event circles (or precedence boxes according to choice) and a ruler or straight edge for drawing the arrows. Initial plans tend to occupy large areas of paper, and certainly far more than can be shown on a computer screen or even an electronic display board, so a roll of paper might be advisable.

Reliable legend has it that one of the earliest American project network diagrams (in the 1950s) was so large that it had to be drawn in chalk on the floor of a hangar, to be photographed for permanent record by a camera mounted in a roof gantry. We certainly do not suggest going to such extreme lengths, but the developing plan must be visible to all those who contribute to its content. We remember with some fondness a planning room where a steel strip screwed to one long wall allowed a long sheet of paper (taken from a roll) to be held in place with magnets, where everyone could see it and help to develop the network. Whatever method is used, it is a great advantage if the entire plan can be viewed at once (not possible on a small computer screen) so that every logical path can be seen in its entirety and traced through from beginning to end.

Pre-drawn horizontal guidelines on the blank paper, ruled at vertical intervals of (say) two or three inches will help the planner to keep the initial sketch neat and legible. If the network is to be drawn from the start in precedence notation it should be possible to devise a shorthand method for sketching task boxes, possibly using a rubber stamp, or self-adhesive pre-printed labels (which can easily be erased by over-sticking plain labels). We mentioned the possible use of Post-It Notes in this context (with some reservations) in the previous chapter.

Tactical Decisions

It is usually the case that minor aspects of project strategy are identified and resolved during initial project planning meetings. For example, when discussing the duration of a task for making a component, the question might arise (and have to be answered) 'Shall we make or buy this part?'

Occasionally decisions might have to be made on design strategy as it is related to manufacture and cost. One of us was once present (as project management consultant) at a highly regarded Illinois engineering company where a planning meeting called by the engineering vice president was attended by design managers, senior engineers and a manager from the manufacturing plant. As tasks were identified and added to the network, the design engineers and the manufacturing manager discussed which design approach would lead to the lowest manufacturing costs. Sometimes this would mean accepting additional design cost and longer durations for design tasks, but the total cost to the organization was the deciding factor. Each chosen design approach was the one considered best for the company, not simply the easiest for the design department to perform. Three new projects were planned at that Illinois meeting as the first to be entered into the company's new computerized project planning and resource scheduling system (using methods described in Chapters 15 and 16). The company's senior managers were later delighted when all three projects were delivered early and well below budget.

In a case in the UK, one of us was acting as external consultant to a large engineering company and, during the course of developing and comparing network diagrams across a large number of simultaneous projects. it emerged that considerable sums of money were being wasted in unnecessary repetition of prototype manufacture and appraisal for some major components. This became apparent as a result of watching the network logic grow during each project planning meeting, but it had not been realized by the company's own staff. Thus the company immediately changed its policy on the use of prototypes and at a stroke cut months from the average duration of a project, with five-figure cost savings on every project.

Thus planning meetings are certainly not only to do with the nuts and bolts of scheduling. Cost effective solutions can and should be expected from them. Indeed, as the two above instances illustrate, the mere act of considering and drawing the network logic can immediately bring

improvements to technical processes, even before the network is used for scheduling.

LEVEL OF DETAIL IN THE PROJECT SCHEDULE

A typical aviation project will require some major tasks, hundreds of departmental tasks, sub-contracted tasks and perhaps millions of small jobs. The question now is which of these tasks should be included in the network diagram for the project and its resulting schedule?

We once knew a pair of planning engineers who were very proud of a network diagram that they had drawn in pencil on an enormous roll of paper, which they claimed contained 10 000 tasks. Of course that plan was far too complex to be of any practical use and all the planners' efforts had been wasted. So including too much detail in a plan can be just as big a mistake as not going into enough detail.

The plan must contain enough information to provide progress monitoring points at regular intervals. It must have enough detail to allow resources to be scheduled to accomplish level usage. Also important is that the schedule must provide the base from which work can be issued to individual people in departments or small groups when the project is in progress.

Fortunately there are some practical approaches that can overcome this apparent problem of how much detail to show in the project network plan.

Breaking a Master Network Diagram Down into Sub-networks

All aviation projects rely on external suppliers and sub-contractors for many major project tasks. In many other instances external companies act in partnership. The plan prepared by the main project contractor cannot possibly show the detailed inner workings of all those external organizations and, even if it could, it would be highly impractical to manage. So the main project plan has to be regarded as a master network or summary framework into which all those external tasks fit.

Each major external task need only appear on the project network as a summary, perhaps comprising only one or two tasks. For example, there might be one task for arranging a contract, another single task to cover all the

sub-contractor's work, with perhaps one or two tasks inserted to highlight approval or review stages.

In the unusual (but not impossible) case where all work is to be sub-contracted, the main contractor's project network diagram might thus need to contain only a very few tasks—even for a multimillion dollar project. However, there is a most important corollary to this argument, which is that the main contractor must be assured by each sub-contractor that every sub-contracted element of the project will itself be adequately planned.

So a very big project might be planned using one master network diagram which interfaces with a number of more detailed network diagrams. The concept of this arrangement is illustrated in Figure 14.1. The points at which any two of these different networks meet are often represented by tasks that are common to both networks, and these will therefore be recognized as *interface* tasks or events.

This concept of a master network diagram interfacing with several sub-networks or satellites is not confined to projects that use external contractors, but can also be applied to simplify planning within the same company, by asking particular departments to carry out their own detailed planning within the framework and constraints of the master network logic and times.

In all such cases, the start and end dates for each sub-network must be arranged to agree with the start and end dates for the corresponding summary task of the master network. Further, the project manager for the main contractor must communicate all relevant schedule changes to those responsible for carrying out the work scheduled in the sub-networks, so that everything and everyone is kept in step with changes.

Interfaces Between Project Planning and Scheduling for Purchasing, Manufacturing, Assembly and Testing

One important set of interfaces occurs in all engineering projects, especially including aviation projects, when instructions leave the design department and are issued for manufacture or assembly.

Just because an aviation project might require thousands of engineering drawings does not mean that the corresponding network schedule will also need to show thousands of tasks. The more usual and practical approach is to consider drawings in sets, with (say) one set for each of the many sub-assemblies.

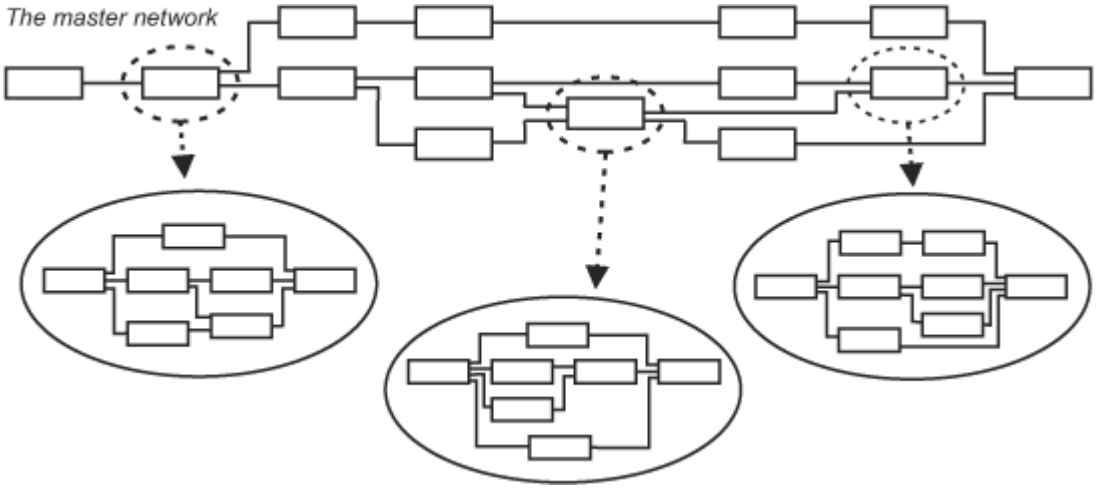


Figure 14.1 A master or summary project network breakdown
Managers produce detailed sub-networks for their departments that interface with the master project network. Partners and external sub-contractors are expected to produce their own separate sub-networks with start and finish times arranged to agree with the master network requirements.

So although a major sub-assembly might require hundreds of drawings, the planner would see it as one integrated design job and the corresponding part of the critical path network might only need to include three tasks. Suppose this sub-assembly were to be a cockpit canopy for a light aircraft. The assembly would in fact need many bought out and manufactured items, a set of drawings and some manufacturing specifications. However the network diagram for this component of the aircraft might need to contain only the following tasks:

1. Layout cockpit canopy (which means producing the master drawing from which subsequent detailing can take place).
2. Detail cockpit canopy (which is just one network task to cover the entire process of expanding the original layout drawing into detail drawings, parts lists and specifications).
3. Check and issue canopy drawings (prudent engineering departments carry out a final check on all related drawings, as a set, before releasing them for manufacture).
4. Purchase canopy materials.
5. Manufacture canopy parts (one network task that implies hundreds of manufacturing operations).

6. Assemble canopy (one network task covering all assembly jobs including inspection).

Of course the materials management and purchasing people will have much work just for this cockpit canopy, in placing orders, expediting them, checking or inspecting the goods on receipt and receiving them into secure storage. The industrial engineers and production controllers in the manufacturing plant will have a considerable amount of planning and control work to do when they receive their pile of drawings. But these far more detailed scheduling procedures are not part of the project manager's remit. Project control can be exercised simply by specifying the network-derived start and finish dates for these tasks, and the relevant departmental and plant managers must then make their own more detailed schedules within that time frame.

Managerial Responsibility as an Indicator of a Desirable Level of Network Detail

The principal reason for planning and scheduling a project is to set out a number of dates when certain actions should start or finish if the project is to progress through to finish at the required time. That timetable of dates will, in turn, allow monitoring to take place so that late running tasks can be identified and action taken to speed up work that is too slow.

Critical progress check times (and new work issue times) occur when each task passes from the responsibility of one group or department to another (which also usually means from the responsibility and care of one supervisor or manager to another). Every one of those checkpoints should be visible in the network diagram and in schedules and work-to lists derived from it. What the planner should learn from this is that a new network task must be created whenever responsibility for a job moves from one manager or department to another. Put the other way, no task should be of such size that it will span two groups or departments, and thus involve the responsibility of more than one supervisor or manager.

To give an example, a job to design, buy, make, assemble and test an aircraft sub-assembly should give rise in the plan to separate network tasks for design, buy, make, assemble and test because each of these tasks falls under the responsibility of a different manager. When the time comes for the

computer to filter and sort tasks from the total schedule, individual departmental managers can then each be given a report containing only those tasks for which they can personally be held responsible (a process made possible by allocating departmental codes to all tasks).

ESTIMATING TASK DURATIONS

Some tasks have almost no duration, yet are important to progress. Prominent among these are stage approvals and engineering design reviews, which might only take a day or two each yet have the potential to interrupt continued progress.

Many tasks occupy time but no effort. Waiting for purchased goods to be delivered, for paint to dry or for goods to be shipped are all examples. Because these tasks take time, their durations have to be estimated. Generally these kinds of estimates present no difficulty because most people know how long to allow for paint to dry and for concrete to set, and the lead-times for bought out goods can generally be assessed well before the orders are placed in the light of experience with previous projects or from actual suppliers' quotations.

Jobs involving design or manufacturing labor are more difficult to estimate, because the amount of work involved and the difficulties that will be encountered are not easy to predict, especially where there is no historic model. Estimates for the duration of such tasks should be obtained from the managers or supervisors of the relevant departments, who should all be present at the initial planning,

Early Consideration of the Relationship between Task Duration and Resource Levels

Jobs that require resources (by which we usually mean people with particular skills) sometimes have durations that will depend on the level of resources that can be assigned to them. For example, a job to connect all the electrical and electronic components distributed over even a small airframe might take one electrical fitter three weeks, two electrical fitters two weeks, three electrical fitters one and a half weeks and so on. Note that the relationship between duration and the number of people assigned is not always linear because as more people enter the confined space of the

airframe, they will get in each other's way to some extent and slow down the work. Indeed there will be a practical upper limit to how many people can be employed.

What the planner needs to know is how many people will actually work on the task and for how long. Will it be one, two or three electrical fitters? The manager who will eventually be responsible for the task should decide, and clearly the answer will determine the duration entered on the network diagram. The answer must also be recorded as part of the data needed for subsequent resource scheduling. The person best qualified to make this operational decision is the manager who will have to assign the people to do the work and manage the task. For this airframe wiring task that means the line manager in charge of the electrical fitters. Line managers for all the other trades likely to be involved in the project should be at the planning meeting, or be represented there by senior delegates, or be available on call to make such advance planning decisions.

Now the estimator (in this case the electrical fitters' line manager) is faced with a dilemma. It cannot be known at this stage how many electricians will actually be available when the time comes to perform the task (which could be many months ahead). The simple rule here is to estimate each task as using the optimum number of people, so that if two fitters for three weeks is considered to be the best and most economical choice for the airframe wiring job, then that decision should be accepted and recorded on the initial network sketch. Provided the electrical department employs at least two fitters, no consideration need be given at this early planning stage to the possible claims of other jobs on the time of those fitters. That consideration must be resolved later, in the separate but related process of resource scheduling (described in the following chapters).

Following these rules means that the brains of planners and managers are not overloaded with impossible problems, but are allowed to solve the problems one at a time, in a logical and sensible sequence.

ROLLING WAVE PLANNING

Some development projects are so complex and profound that they will last for many years and involve thousands of tasks, many of which are so far into the future that no one can know exactly what conditions will exist when the time arrives to perform them. All projects incur changes and it is

unreasonable to ask any planner or planning meeting to attempt a detailed project schedule to cover work so far ahead. However, we can assume that even a 20-year project will have been defined sufficiently for a business plan to be made, and at least the major work packages should be known, even if new technology will be employed in the future to accomplish them.

It is a requirement in every critical path network that there must be a path through to the end of the project. Otherwise forward and back passes could not be made to find the critical path and calculate float for all the tasks. So here we have an apparent problem. The project extends so far into the future that no one can imagine what day-to-day tasks will be taking place near the end of the project, yet it is necessary to draw the network right through to the end if we are to conduct time analysis and extract prioritized work schedules (with associated resource scheduling).

One solution is to identify a project milestone or key event, say one year into the future, and assign a target completion date to it in the computer. Then the project can be planned adequately up to that milestone, to and from which forward and backward passes will calculate time analysis for all the first year tasks.

A more complete solution adopted to overcome this difficulty in planning long-term projects is known as rolling wave planning. The process involves planning the project in normal detail, to obtain working schedules, for as far into the future as practicable. This might be for six months or a couple of years, depending on the nature of the project and how much is known about the future. Then each of the remaining work packages or large tasks that can be foreseen in outline is added to the network as one summary task. That will allow all tasks to be connected in the network through to the final task at the distant end of the project. Thus we have a network that contains many detailed tasks at its front end, but either abruptly or gradually changes in its level of detail as the plan advances towards project completion, so that only very coarse, ill-defined tasks are included in the later stages.

Now the project members have a well detailed day-by-day working schedule that will see them through the first few months of the project. Later, as more becomes known about the project with experience gained, the detailed section of the network can be rolled forward by a few more months, so that some of the coarse summary tasks representing whole work packages get broken down into far more detail. As the work proceeds and time passes,

this process is repeated at suitable intervals, and the detailed portion of the plan can be extended into the future, like a wave rolling forward with time.

USE OF PERT TO RESOLVE UNCERTAINTY IN ESTIMATED TASK DURATIONS

One early variant of critical path planning recognized that duration estimates are subjective, not facts set in stone, and cannot always be regarded as reliable. To overcome this difficulty, this method gives the planner the opportunity to make three estimates for some or all of the network tasks. These three estimates are:

1. The most pessimistic time.
2. The most likely time.
3. The most optimistic time.

The method is known as PERT (Program Evaluation and Review Technique). It was originally based on arrow notation but survives today in precedence networks. The name is also applied erroneously to network analysis in general by some people, which really does not matter. However, we shall adhere to the accurate definition throughout this book.

All good project management software can accept the three time estimates for each task, although a single estimate is the customary default condition. We can illustrate the PERT process using a case example adapted from a previous book (Flouris and Lock, 2008).

HANGAR RESTORATION PROJECT: A CASE EXAMPLE PLANNED USING PERT

Project Description

CEN-CONSTRUCT is a medium-sized business located in Sydney, Australia that is owned and operated by a family. It is principally a consulting company that specializes in aviation civil engineering, having worked on runway construction and paving projects as well as several other airport airside projects, most of which have been for smaller general airports. Having

decided to extend its range of operations, the company recognized a local need for a contractor that could carry out aircraft hangar renovation. In consequence, the company has now achieved a good level of expertise in the interior design and renovation of hangars.

The subject of this case example is the renovation of a hangar for a small client at a general aviation airport. The client uses the hangar to house his Cessna 310 twin-engine plane. The hangar was originally built in 1950, since when no further construction or renovation work has been carried out. CEN-CONSTRUCT had no previous integrated project management system or strategy for this type of project, so the project management planning steps described here were implemented for them.

Project Task List

Because the total number of identified tasks was small, a simple task list sufficed for the WBS This list, given in Figure 14.2, defines the project scope. The cost estimates show that the total original estimated cost for this project was $46 900.

Note that each task has been given four different values for its estimated duration and, to explain those, we need now to explain how PERT estimates are made and assessed.

The PERT estimating method

Almost all duration estimates are a matter for subjective judgment and the actual time taken to finish each task can be quite different from the planner's original intention and estimate. PERT recognizes this uncertainty. Each person who estimates the duration of a task is asked to give three possible values which are:

t_m = the most likely estimated time

t_o = the most optimistic estimated time

t_p = the most pessimistic estimated time

Task ID	Task description	Estimated duration (days)				Estimated cost
		Most likely	Opti-mistic	Pess-imistic	Expected time	$
1	Establish customer specification and budget	10	5	15	10.0	800
2	Design new hangar features	9	7	12	12.2	1 500
3	Agree and sign contract	2	1	3	2.0	3 000
4	Buy materials	5	3	10	5.5	3 000
5	Remove redundant fixtures	2	1	3	2.0	500
6	Clean and strip floor	7	5	9	7.0	4 000
7	Set pipes and valves	4	2	7	4.2	4 000
8	New electrical wiring	4	2	7	4.2	5 000
9	Install ventilation and air conditioning ducts	5	3	7	5.0	6 500
10	Install toilet and shower	5	3	8	5.2	4 500
11	Install storage cabinet for aircraft spares etc.	10	5	12	9.5	5 000
12	New floor screed	9	5	13	9.0	7 000
13	Paint	5	4	7	5.2	1 000
14	Install lamps and electrical appliances	2	1	3	2.0	500
15	Final finishing and clean up	3	2	4	3.0	600
16	Hand over hangar to the client	1	1	1	1.0	0
Total expected project cost:						$46 900

Figure 14.2 Task list for the hangar restoration project with PERT time estimates

These values are inserted in the following formula for each task to give the most probable or *expected* time, which is based on the standard deviation from a normal statistical distribution curve:

$$t_e = (t_o + 4t_m + t_p)/6$$

That explains why there are four columns for task duration in Figure 14.2.

Some project managers believe that all estimators err on the side of optimism, and they use the following slight adaptation of the formula, which skews all the expected times toward the pessimistic end of their timescale.

$$t_e = (t_o + 3t_m + 2t_p)/6$$

The Network Diagram for the Hangar Restoration Project

The network diagram, using expected duration values, is shown in Figure 14.3. Time analysis has revealed the critical path, which is shown in bold lines. The expected product duration is 67.9 days.

Note that two dummy tasks, identified as *A* and *B*, have been inserted in the network diagram to clarify the logic drawing and make it easier to follow. These dummy tasks do not affect the network logic (work sequence) and as they both have zero duration they do not affect time analysis. We

outlined this method for clarifying some aspects of precedence diagrams in the previous chapter (see Figure 13.11).

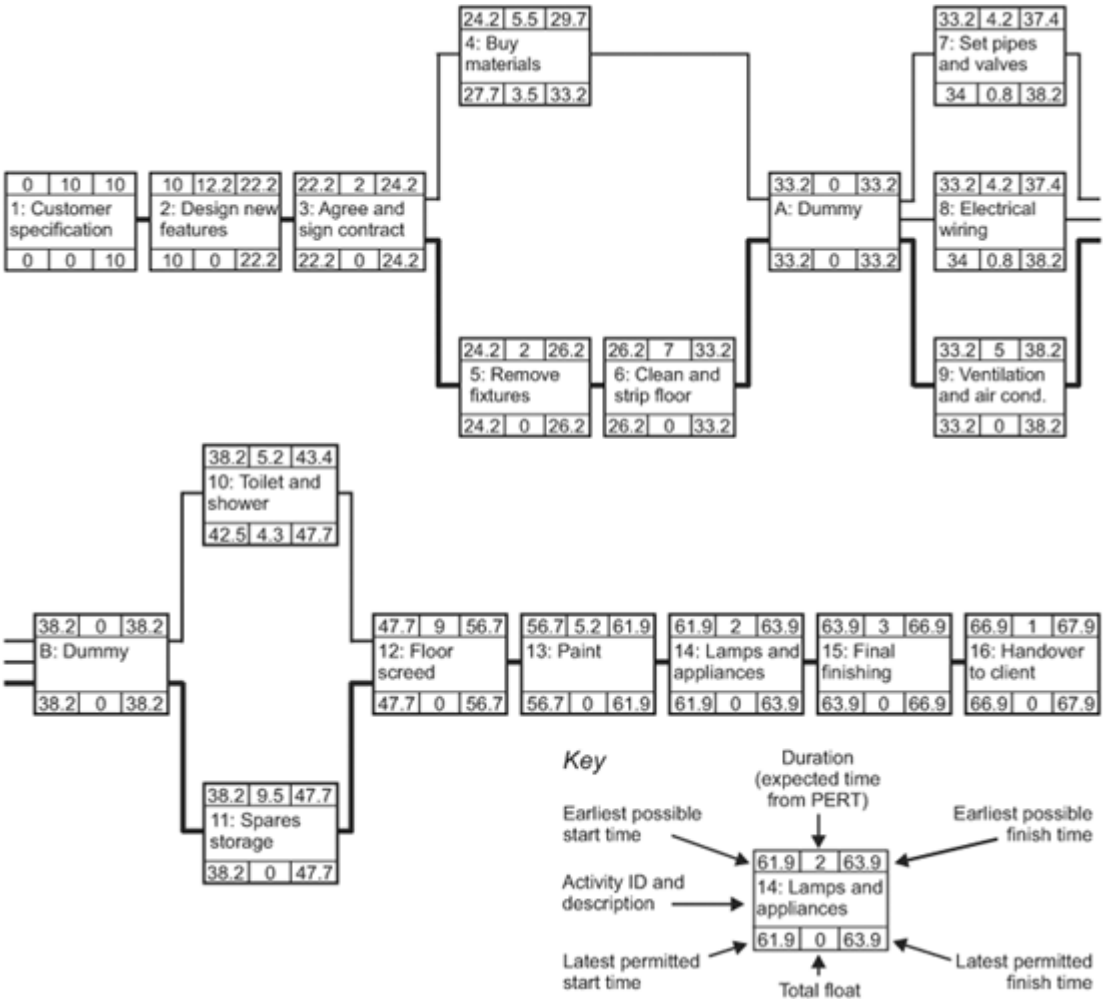


Figure 14.3 Network diagram for the hangar restoration project with PERT expected times

WHAT IF THE PREDICTED TIMESCALE IS TOO LONG?

More often than not, the first predictions for the duration of a new project from time analysis give rise to shock and disappointment. Cries of horror from senior managers to the effect that ‘We need it far earlier than that’ or ‘You are predicting midsummer completion but the customer expects it by Easter’.

The hangar restoration project can be used to illustrate this kind of problem and its solutions. However, from now on (and throughout the remainder of the book) we shall plan using only the most likely task duration times because that is by far the most common approach. In practice relatively few people use the PERT probabilistic method with its requirement for three time estimates for every task.

The network diagram shown in Figure 14.3 still applies except that now the most likely times are the only times used to calculate time analysis. The time analysis results are tabulated in Figure 14.4 and using only the most likely times has changed the estimated project duration from the former 67.9 days to 65 days. The usual working week is 5 days, so this project is predicted to last for 13 weeks. That is provided it actually starts on day 1 (which means the beginning of day 1, equivalent to day 0 on the network diagram).

For practical purposes we need to work in calendar dates, so suppose that the hangar restoration project could begin on Monday 2 April 2012. A project duration of 13 weeks would translate in calendar terms to completion on Friday 29 June 2012. For simplicity this ignores any possible public holidays, although these would be programmed into the computer calendar and allowed for in practice. So now the project manager can tell the aircraft owner that the hangar will be ready for use after close of work on 29 June. But this project owner wants to take occupation no later than 25 May. So now the project manager has a problem. The project schedule must be shortened if the customer is to be satisfied.

Two possible approaches to achieving this solution will now be outlined. These are time/cost optimization and fast-tracking.

TIME/COST OPTIMIZATION THROUGH CRASHING

Perhaps the most obvious way to reduce the duration of any project is to throw more money and resources at it. Working a seven-day week and accepting the higher costs of overtime would be one simple way. For this hangar restoration project, that would reduce the estimated project duration from 13 weeks to nine weeks and two days. The predicted completion date would advance from Friday, 29 June to Tuesday, 5 June 2012. Other options would include working shifts, so that work could continue all night. Again, that would increase costs but one can see that the owner's delivery

requirement might easily be achieved by these overtime and shift working measures.

In other projects there are many possible ways of reducing task times, such as using fast-setting concrete, floodlighting open-air work so that work can continue through the hours of darkness, hiring heavier tools and machines that can get jobs done faster and so on.

All this is fine but all these measures are likely to increase the project overall cost. So some degree of restraint has to be exercised, and only those tasks that are critical should be shortened by using these accelerating methods (which are usually referred to as crashing the times).

In the hangar restoration project, of the 16 total tasks, 12 are critical. Clearly these should be considered for crashing first. However, when each task is examined separately, it is usually found that some tasks cost less to accelerate than others. It is even theoretically possible to calculate a cost per day saved. For example, if task 12, floor screed, could be shortened from its estimated nine days down to only five days for an additional cost of $2000, one could argue that these four days have been saved at a cost of $500 per day saved. Now suppose that task 11, installing a storage cabinet, could be done in only six days instead of ten. Again this would save four days, but suppose now that the additional cost would only be $1600. So this task could be shorted for a cost of only $400 extra for each day saved.

Task ID	*Task description*	*Dur (days)*	*Early start*	*Early finish*	*Latest start*	*Latest finish*	*Total float*	*Est. cost $*
1	Establish customer specification and budget	10	1	10	1	10	0	800
2	Design new hangar features	9	10	19	10	19	0	1 500
3	Agree and sign contract	2	19	21	19	21	0	3 000
4	Buy materials	5	21	26	25	30	4	3 000
5	Remove redundant fixtures	2	21	23	21	23	0	500
6	Clean and strip floor	7	23	30	23	30	0	4 000
7	Set pipes and valves	4	30	34	31	35	1	4 000
8	New electrical wiring	4	30	34	31	35	1	5 000
9	Install ventilation and air conditioning ducts	5	30	35	30	35	0	6 500
10	Install toilet and shower	5	35	40	40	45	5	4 500
11	Install storage cabinet for aircraft spares etc.	10	35	45	35	45	0	5 000
12	New floor screed	9	45	54	45	54	0	7 000
13	Paint	5	54	59	54	59	0	1 000
14	Install lamps and electrical appliances	2	59	61	59	61	0	500
15	Final finishing and clean up	3	61	64	61	64	0	600
16	Hand over hangar to the client	1	64	65	64	65	0	0
Total expected project cost:								$46 900

Figure 14.4 Time analysis for the aircraft hangar restoration project with single task time estimates (the planner's estimates of the most likely task durations)

There is one more factor to be taken into account, which is that in many project network diagrams if critical tasks are crashed by more than a given time, they cease to be critical. New critical paths are created, and new critical tasks can be considered for crash action in their turn.

Theoretically, and taken to extremes, the time/cost optimization process means applying crash actions sparingly, choosing first those tasks that have the lowest cost per day saved, and carrying through the exercise until virtually all tasks have become critical. Not many, if any, project managers go to such extremes but the principles are sound. So the practical advice for any aviation project manager who needs to shorten a project's planned timescale using crash actions is to start by crashing only critical tasks, and give priority to spending the extra money to those tasks which have the lowest cost per day saved.

Using crash/time optimization should bring forward the delivery date of the hangar restoration project date to suit the project owner's required date of 25 May 2012. However, that might not solve the project manager's problem, because the owner might not be willing to accept the higher project price that the additional costs would precipitate.

FAST-TRACKING TO ACCELERATE PROJECT DELIVERY WITHOUT ADDING COST

One reason why a network diagram can suggest a timescale that is too long is that, in practice, some of the junctions between different tasks are not as definite and clear cut as the network logic would suggest. For example, an engineering design task is often followed by a purchasing task which can include buying bearings, motors, castings or other components that have to be specially manufactured and will take several months to obtain. All good engineering companies know that in such cases the beginning of any purchasing task should start with the long-lead items, and that engineers should release information for that to happen some time before the entire engineering design task is finished. In other words, the beginning of purchasing overlaps the end of design. It was possible, using somewhat clumsy logic, called ladder networks, to show such overlaps in arrow

diagrams. But with the precedence system there is far more scope to specify complex relationships at task interfaces. The method is elegant and supported by all the good software.

There are four possible ways of indicating sequential links in a precedence network and these are illustrated in Figure 14.5. By far the most common link used is the finish-start relationship shown at Figure 14.5(a), which is the default condition assumed in all project management software. There are various circumstances in which one or more of the other three link options can be used in projects, and Devaux (1999) explains and illustrates these particularly well.

For our purposes, when attempting to accelerate a project by overlapping tasks, the two relationships shown at (b) and (c) in Figure 14.5 will apply. The start-start relationship is used to indicate the way in which a task may begin after its predecessor has been in progress for a specified time. For example, in the hangar restoration project, it might be concluded that since the floor area is so large, task 13 (paint) can begin at one end of the hangar whilst the floor people are still working at the other. When a start-start relationship has been specified in this way, care must be taken not to leave the end of the preceding task dangling. To avoid that one must add a finish-finish link to pin down the end of the second task. All this is illustrated by the portion of the CEN-CONSTRUCT hangar renovation network shown in Figure 14.6, where it can be seen that this particular overlap has shortened the critical path by three days.

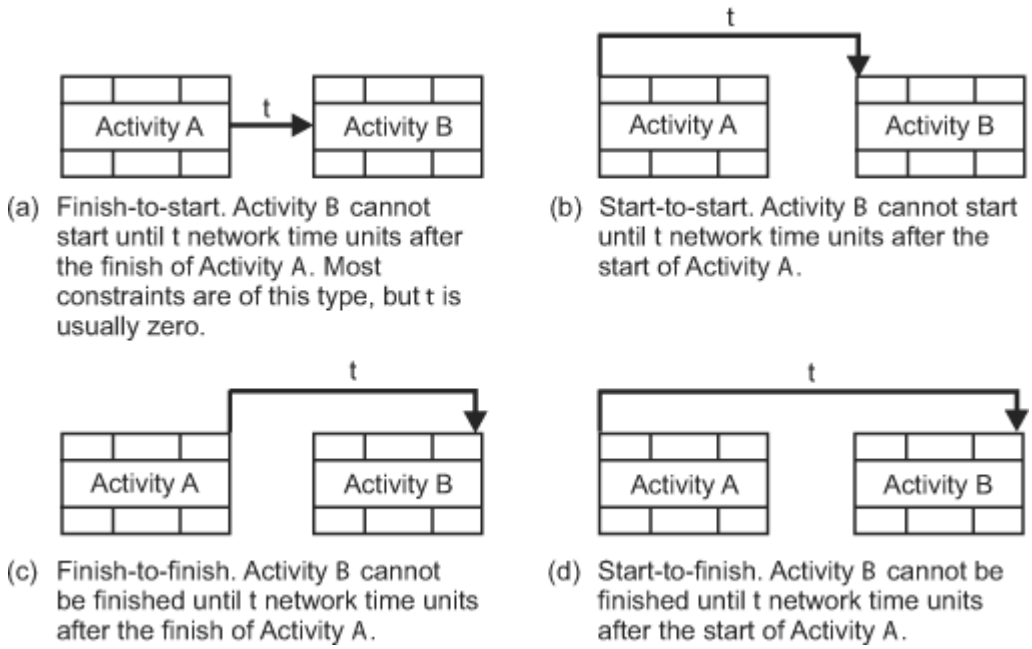

Activity A
t
Activity B
(a) Finish-to-start. Activity B cannot start until t network time units after the finish of Activity A. Most constraints are of this type, but t is usually zero.
t
Activity A
Activity B
(b) Start-to-start. Activity B cannot start until t network time units after the start of Activity A.
t
Activity A
Activity B
(c) Finish-to-finish. Activity B cannot be finished until t network time units after the finish of Activity A.
t
Activity A
Activity B
(d) Start-to-finish. Activity B cannot be finished until t network time units after the start of Activity A.

Figure 14.5 Constraint options in precedence networks
The different kinds of links that can be used in a precedence network.

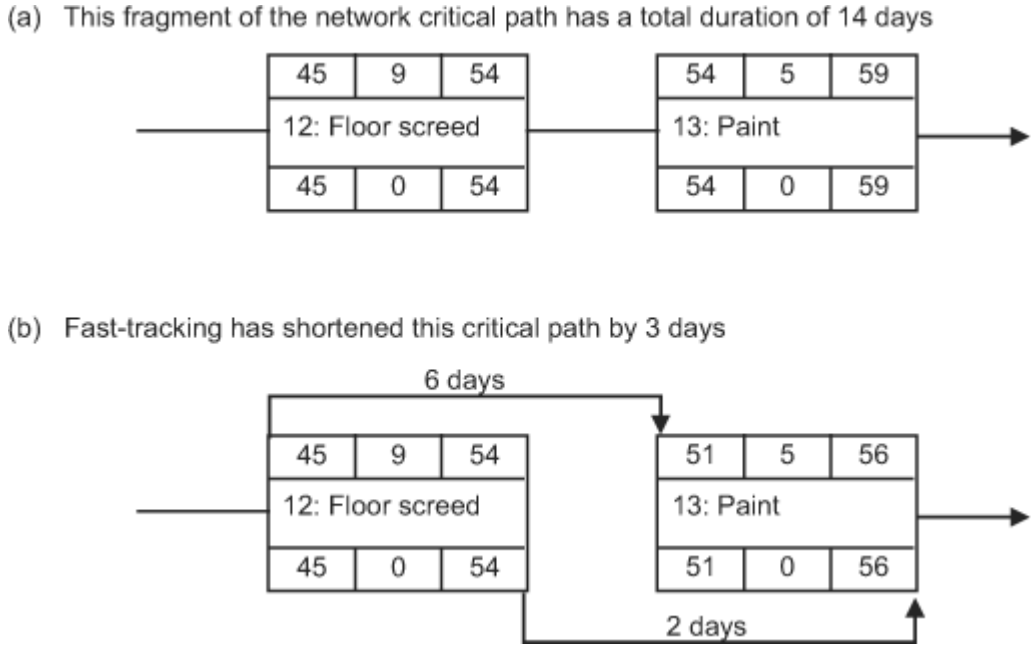


Figure 14.6 Fast-tracking applied to part of the hangar restoration project network diagram

Substantial time can often be saved by re-examining the entire network logic and overlapping all suitable tasks. The advantage of fast-tracking when compared with crashing is that it does not usually add any cost. However it

can introduce some risk because any task started before all the information from its predecessor is known might have to be scrapped and reworked if errors are found when the predecessor is finally finished and checked.

EXTREME MEASURES

The two methods just described, crashing and fast-tracking are not mutually exclusive. When a project has to be finished in the very shortest time possible, that is no reason why both methods should not be used together. Possibly the best approach is to optimize the logic by fast-tracking first. Then, if necessary, additional costs can be incurred by crashing tasks on the critical path and following through with complete time/cost optimization. Not many people go to those extreme lengths, but the option is there for those who are interested and sufficiently brave.

REFERENCES

Devaux, S.A., (1999), *Total Project Control: A Manager's Guide to Integrated Planning, Measuring and Tracking*, New York, Wiley.

Flouris T. and Lock D., (2008), *Aviation Project Management*, Aldershot, Ashgate.

15
Principles of Resource Scheduling

Resource scheduling, otherwise known as resource allocation or resource leveling, is a process that follows on from the initial planning calculations made with critical path network analysis (described in the previous two chapters). When the initial network scheduling has been completed successfully the project manager will know:

- all the project tasks that need to be scheduled and progressed;
- the estimated duration of each task and, where appropriate, the optimum level of resources to be employed on the task (which usually means how many people of each relevant skill);
- the earliest possible times when each task could be expected to start and finish;
- the latest permissible times when each task can be allowed to start and finish if the project is not to be delayed;
- the amount of total float possessed by each task.

Now comes the question of blending the project organization's resources to the plan. This usually means considering people of different qualifications and skills, and timing their tasks so that the demand for each type of resource is kept as level as possible. The aim must be to avoid alternating overloads and idle periods that would result in inefficient working. But the project must still be completed on time if that is possible with the resources available. A perfect solution is seldom possible because when one resource is scheduled it can throw out the best timetable for activities using other resources. Attempts to reach a near perfect solution covering all resources are known as resource optimization. Broadly speaking, the greater the number of project tasks, the more likely it will be that a smooth schedule can be produced.

When several projects are active at the same time in an organization, clearly all of them will have to be put into one resource scheduling pot, so

that one project is not scheduled well at the expense of all the others. Fortunately that aspect of resource scheduling, which will be described later in these chapters, is just as easy to accomplish as single project scheduling, provided good software is available and is used with commonsense.

THE NATURE OF PROJECT RESOURCES

Project resource scheduling usually means allocating people with different trades and skills to tasks. But people are by no means the only kind of resources that can be scheduled using one of the widely available project management software packages. A description follows of the resources that might be needed by projects.

Reusable Resources

Some resources can be considered as reusable. They exist at the beginning of a project and remain available if required for reuse on future projects. Rather like catalysts in chemical reactions, they are important in causing the project activities to take place but they emerge unchanged at the end of the project. People usually fall squarely into this class of resource because once a project is ended they should be available in the organization to work on the next. They can of course be changed for better or worse by their project experience. Also, the number of people available in the organization can change because of recruitments and departures. However, people are generally a reusable resource. So are most machines and tools, unless they get damaged or are lost or stolen.

Reusable resources usually exist in finite quantities in the organization, so that there are limits to the total quantity that can be used at any given time. They have the useful attribute of being relatively easy to cost, because every reusable resource can be given its own hourly, daily or weekly cost rate. Thus the cost per task will be directly proportional to the amount of time for which each resource unit is used on the task.

Replenishable Resources

Some resources exist in finite quantities that become depleted as the project proceeds, but can be replenished by buying more. Many materials are of this

nature and most will not need scheduling. Shortages must be foreseen so that repurchasing takes place in time to prevent project hold ups, but these replenishable resources do not have to form part of the resource scheduling process and will not be mentioned again in this context.

Materials usage can be scheduled, if required, so that their costs are taken into account in the value of work in progress. Project resource scheduling software can do this, but ordinary cost accounting procedures will usually do the job far better. Materials deliveries sometimes require scheduling to prevent overloading storage areas, but we shall not consider that application. There is a case for scheduling materials purchases as part of a cash flow management process but, although that is important, it is a more advanced and less usual application of project management software and we have deferred discussion of that subject until Chapter 25.

Money with which to buy materials, pay wages and fund all other project activities is usually a replenishable resource (even though that might sound astonishing to any reader experiencing a personal cash flow crisis). If a project organization overspends and needs to borrow more funds, any bank that has already invested in the project should feel some incentive to inject more cash to keep the project alive if the only alternative is to see the project fail and lose all the costs already invested in work in progress. Of course there are limits to that argument and many exceptions but a failed project can lose its investors all their money and there have been many cases of seriously overspent projects being kept alive by 'restructuring' the financing arrangements. But of course every competent project manager will strive to keep the project within its original budget. A call for more funding is clearly an indication of failure somewhere in the project management or general management process.

Exhaustible Resources

Some resources are finite. Once used, they cannot ever be replaced. Fossil fuels and some mineral deposits are in this category, when considered over a long term. There are a few instances of exhaustible resources causing scheduling difficulties in projects. Restoration projects are one example, where it would be difficult or impossible to obtain new materials or components. Consider a case where a historic aircraft has survived for many decades and is now the only one of its kind still airworthy. Now that really is

an exhaustible resource. It will certainly be 'exhausted' if an accident causes terminal damage during a maintenance or restoration project.

Exhaustible resources are important in some project feasibility studies, business plans and project financial appraisal studies. The long-term viability of projects to extract oil, gas, minerals, metal ores and other earth resources will always depend on the total amount of resource existing at the project site. However, those considerations clearly have little to do with the management of aviation projects, so can be ignored for our purposes.

Resources that can be Scheduled using Project Management Methods

Computers work best with numbers and any resource that can be quantified using simple numbers or one-dimensional units can be scheduled with good project management software. The usual application is when people of a specified trade or skill are to be allocated to project tasks from a group or department. If required, money and materials can also be scheduled because their amounts are also quantifiable by simple units of quantity.

Resources that do not Need to be Scheduled by the Project Manager

Consider a project where an aviation company manages the project as main contractor, but lets out many tasks to sub-contractors or other companies working in partnership. This is very common in large aircraft development projects. The overall project manager employed by the main contractor will certainly have to arrange for resources such as design engineers working in the home office or people working on final assembly of the aircraft to be scheduled. But that project manager would not be expected to schedule the time or the detailed tasks of the hundreds or thousands of outworkers in the premises of all the sub-contractors and partners because that would be the responsibility of the individual companies that employed the labor directly.

A project might use many different kinds of labor resource, but it is seldom wise or necessary to attempt to schedule all of them. The organization will know from experience which resources (in other words which skills or trades) usually become overloaded and cause delays. If one or two key resource types can be identified, it is often only necessary to schedule those, and all the other resources will get used in a smooth, manageable work pattern. To give some examples, paint shop personnel will

not need to be scheduled if the plant manufacturing operatives are scheduled because we can be reasonably confident that work will arrive at the paint shop in a smooth flow. From our own experience, in one engineering department containing 150 staff it was not necessary to schedule the time of the small number of control and lubrication engineers, because by scheduling the mainstream layout design engineers all work was leveled and the demands on specialist engineers were made at a smooth rate.

Many project managers go through their working lives without considering resource scheduling at all. They expect all line managers to get every job done on or near its earliest time. These project managers consider that their scheduling task is done when they issue Gantt charts or work-to-do lists based only on network time analysis. They might be lucky, especially where temporary labor can be hired at short notice to cope with overloads. However we have personally seen in several different cases the cost and time savings that project resource scheduling can bring to companies.

Resources that Cannot be Scheduled using Project Management Methods

The most difficult resource to schedule using project management methods and software is working space. Space can be certainly quantified by units of area, but shape usually comes into the equation. So different software must be used, and this takes the scheduling process more into the realms of the facilities manager. Assembly space can be even more difficult to schedule because the work pieces (which can include whole aircraft) can be allowed to overhang some other objects and the problem becomes three-dimensional. That is certainly not a job for project management methods, and falls more logically within the ambit of industrial engineers, who might even use scale models to solve such problems.

RESOURCE SCHEDULING WITHOUT A COMPUTER

For many years the only method available to project managers for resource scheduling was to use a Gantt chart with special features:

- each bar representing a task could be moved sideways, or in other words adjusted in time;

- each bar represented one unit of resource along its entire length (it was possible to write on the bar to indicate a multiple number of units, but that made the method more difficult to apply);
- if more than one type of resource was to be scheduled in the plan, then some kind of coding had to be used to show which of these types each bar represented. The usual way was to use colored strips for the bars, with each color denoting a different kind of resource;
- more likely than not, the chart would eventually be wall-mounted, and several proprietary kits were sold that could make the scheduling job easier. One successful system even used Lego bricks on a pegboard.

For extremely simple cases such systems can still be used (although we do not recommend their use). In one sense they survive, in printed paper sheets used as holiday charts in small departments. These are a very simple form of resource scheduling that can prevent allowing too many people to be on vacation at one time from one group.

Adjustable Gantt charts have been supplanted for all but the very tiniest project by powerful project management software that can perform a variety of resource and cost scheduling processes. However, using the old-fashioned Gantt chart method is an ideal way to demonstrate the essential principles, and we can do that by means of a very small project case example.

A GANTT CHART RESOURCE SCHEDULING CASE EXAMPLE

Project Description

Sheep Island is privately owned, with a small population of people who make their living from sheep, by farming them and using their fleeces for weaving and woolen textile manufacture. Their lifestyle is not unlike the Harris Tweed workers in the Scottish Hebridean islands, but this Sheep Island is located off Canada and generally has a mild maritime climate. Tourists love the place for its walks, wildlife and beautiful scenery but the landscape is hilly and rocky, with no possibility of building an airstrip. So the only way to traverse the 75 miles of sea is by a daily ferry service. The island's small harbor is the only portal through which heavy goods can be

imported to the island. It is also the exit point for the island's woolen exports.

The island's owner has decided to provide accommodation and facilities that will encourage more tourists (and generate more wealth for the island). Our interest is in the Sheep Island heliport project that is to be built on a small plateau to allow a regular commercial helicopter service with the mainland. The island's owners will eventually set up a tiny management company to operate the heliport, with one manager and a handful of staff. But first the heliport must be built, and that will need some project management.

The Sheep Island heliport will have the following very basic facilities when the passenger, mail and light freight service opens:

- a tarmac-on-concrete landing pad, with clear markings;
- a tarmac helicopter parking area, adjoining the pad;
- a refueling facility for the helicopters (fuel will be delivered by sea transport);
- a small building close by the tarmac with a rest lounge, small kitchen and toilet solely for the use of pilots;
- a terminal building combining a ticket office, check-in room for baggage and people, small office, public refreshment room and toilets;
- security fencing to protect the facilities and visiting aircraft and keep stray animals and people away from the tarmac.

Barring the grounding of flights by bad weather, it is not expected that any helicopter will remain on the island overnight. With flights expected to take place only at hourly intervals, no control tower or ATC arrangements are considered necessary, at least for the first year of operations.

Mainland-based contractors will ship in labor and materials, install the refueling equipment and lay the concrete and tarmac for the aircraft areas. However, there is a small family-run construction business on the island that will construct the two buildings and they will be capable of all the construction tasks needed for that job. Their workers fall into two different categories for the purposes of resource scheduling:

- people with good all-round skills who can build, install plumbing and wire up all the lights and electrical outlets (if we had been using a computer we might have coded them as S for skilled);

- people with no special skills, who can act as general laborers, assist the skilled people, or carry out some construction tasks under supervision (whom we could code as A for assistants).

There are four skilled construction people available on Sheep Island who can be freed from their other work. The island's owners are adamant that they will not incur the expense of importing labor from the mainland. So the project tasks will have to be scheduled so that no more than four skilled people are needed at the same time.

There are plenty of unskilled people who can be deployed on this project when needed and there is really no need to schedule them.

Our small project takes the construction tasks up to the point where the buildings can be handed over to the manager of the Sheep Island heliport operating company, and she will be responsible for ordering furniture and other supplies, arranging for telephones, setting up local contracts for utilities and so on.

The task list shown in Figure 15.1 covers only the erection of the two buildings at the heliport (or, in other words, only the tasks to be performed by local people). None of its activities are linked in any way to the other construction tasks such as fencing and laying tarmac, so we can safely plan and schedule these tasks on their own. A network diagram was drawn using this task list, but it was too big to print in these pages. However, we have included the time analysis results in Figure 15.1 and these will be of considerable use in resource scheduling. Early users of Gantt charts for resource scheduling did not have that advantage.

A Gantt Chart for the Sheep Island Heliport Buildings

The Gantt chart shown in Figure 15.2 shows all the main tasks for the heliport buildings placed at their earliest possible times, as indicated from the network analysis results. As we are not going to consider the unskilled people for resource scheduling, we have not indicated their requirements separately on the chart.

Each solid black bar represents the employment of one skilled person on a task. For a few tasks it can be seen from the data in Figure 15.1 that two skilled people will be needed, so this is represented on the Gantt chart by placing two solid black bars side by side.

It will be noticed that many of the bars representing project tasks have tails extending from them to the right, shown as white bars with dotted line borders. These represent the total float possessed by each task. Clearly the critical tasks (tasks with zero float) can have no such tails.

	Pilot's building	*Estimated duration*	*Early start*	*Early finish*	*Late start*	*Late finish*	*Total float*	*Resources needed*
1	Dig for drains and utilities	2	0	2	50	52	50	2A
2	Lay concrete foundation slab	1	2	3	52	53	50	1S, 1A
3	Concrete setting time	5	3	8	53	58	50	-
4	Lay damp proof membrane	1	8	9	58	59	50	1S, 1A
5	Build all brick walls	5	9	14	59	64	50	1S, 1A
6	Construct roof frame	5	14	19	64	69	50	1S, 1A
7	Fit corrugated roof sheets	3	19	22	69	72	50	1S, 1A
8	Build internal partition walls	6	14	20	64	70	50	1S, 1A
9	Install windows	2	14	16	70	72	56	1S
10	Install ceilings	2	20	22	70	72	50	1S, 1A
11	Install electrics	2	22	24	72	74	50	1S
12	Install toilet plumbing	1	22	23	82	83	60	1S, 1A
13	Install kitchen plumbing	2	22	24	81	83	59	1S, 1A
14	Install kitchen units	2	24	26	81	83	57	1S, 1A
15	Install electric heater	1	24	25	74	89	64	1S
16	Install doors	2	22	24	81	83	59	1S, 1A
17	Install cupboard and shelves	2	22	24	81	83	59	1S, 1A
18	Floor coverings	3	29	32	86	89	57	1S
19	All painting and final finishes	3	26	29	83	86	57	1S
	Terminal building							
20	Mark out the building plot	1	0	1	0	1	0	1S, 1A
21	Dig for drains and utilities	3	1	4	1	4	0	2A
22	Dig foundations	2	1	3	1	3	1	2A
23	Concrete wall foundations	2	4	6	4	6	0	2A
24	Concrete setting time	5	6	11	6	11	0	-
25	Build brick walls	15	11	26	11	26	0	2S, 1A
26	Construct roof frame	5	26	31	26	31	0	2S, 2A
27	Tile roof	8	31	39	31	39	0	1S, 1A
28	Fit gutters and rain pipes	2	39	41	67	69	28	1S, 1A
29	Build entrance ramp	1	26	27	88	89	62	2A
30	Build partition walls	5	39	44	39	44	0	2S, 2A
31	Install ceilings	5	44	49	44	49	0	2S, 2A

32	Install windows	3	26	29	36	39	10	1S, 1A
33	Install electrics	5	49	54	49	54	0	1S
34	Install plumbing to toilets	3	49	52	66	69	17	1S, 1A
35	Install plumbing to kitchen	3	49	52	63	66	14	1S, 1A
36	Install kitchen appliances	2	54	56	67	69	13	1S, 1A
37	Install kitchen cupboards	3	52	55	66	69	14	1S, 1A
38	Install oil fired central heating	15	54	69	54	69	0	2S
39	Install shelving, cupboards	3	49	52	66	69	17	1S
40	Install doors	3	44	47	66	69	22	2S, 2A
41	Floor coverings	10	79	89	79	89	0	2S
42	Install signs	1	79	80	88	89	9	1S
43	Paint	10	69	79	69	79	0	2S

All times are days

Figure 15.1 Sheep Island heliport project task list for the terminal and pilots' lounge

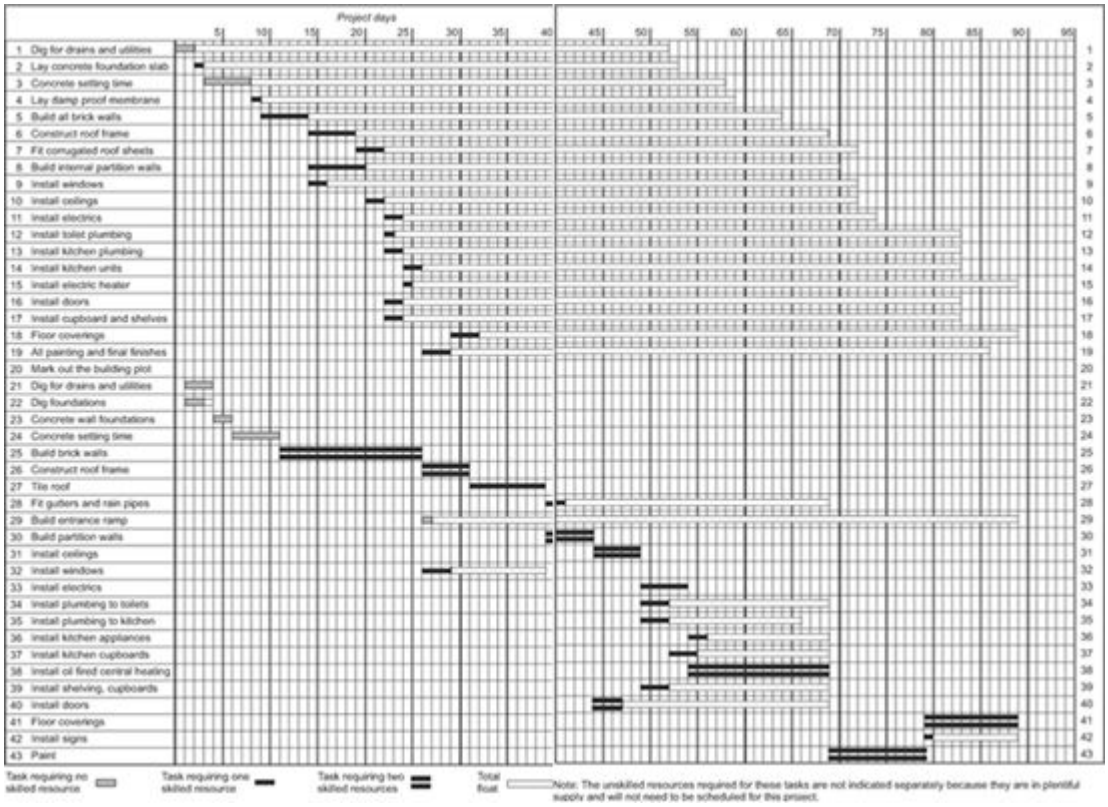

Project days
1 Dig for drains and utilities
2 Lay concrete foundation slab
3 Concrete setting time
4 Lay damp proof membrane
5 Build all brick walls
6 Construct roof frame
7 Fit corrugated roof sheets
8 Build internal partition walls
9 Install windows
10 Install ceilings
11 Install electrics
12 Install toilet plumbing
13 Install kitchen plumbing
14 Install kitchen units
15 Install electric heater
16 Install doors
17 Install cupboard and shelves
18 Floor coverings
19 All painting and final finishes
20 Mark out the building plot
21 Dig for drains and utilities
22 Dig foundations
23 Concrete wall foundations
24 Concrete setting time
25 Build brick walls
26 Construct roof frame
27 Tile roof
28 Fit gutters and rain pipes
29 Build entrance ramp
30 Build partition walls
31 Install ceilings
32 Install windows
33 Install electrics
34 Install plumbing to toilets
35 Install plumbing to kitchen
36 Install kitchen appliances
37 Install kitchen cupboards
38 Install oil fired central heating
39 Install shelving, cupboards
40 Install doors
41 Floor coverings
42 Install signs
43 Paint
Task requiring no skilled resource
Task requiring one skilled resource
Task requiring two skilled resources
Total float
Note: The unskilled resources required for these tasks are not indicated separately because they are in plentiful supply and will not need to be scheduled for this project.

Figure 15.2 Sheep Island Heliport project Gantt chart before resource scheduling

Note that many of the tasks toward the top of the chart have considerable amounts of float. These are the tasks for constructing the pilots' building. Thus priority in general must be given to tasks for the small terminal building.

Results of Resource Scheduling

Resource aggregation Histograms are often used to display resource requirements against time and the upper illustration in Figure 15.3 shows the resource usage pattern that would result for skilled people if the project manager attempted to perform each building task on Sheep Island at its earliest possible time. The usage pattern is unsatisfactory for two reasons:

1. peak loads require up to seven skilled people but only four are available on the island;
2. the day-to-day usage pattern fluctuates wildly.

The uneven pattern that results from trying to do everything as early as possible is called resource aggregation. Clearly we need to do something better than that on Sheep Island.

Resource leveling The lower picture in Figure 15.3 shows how the project manager was able to delay the planned start of some tasks to produce a far smoother resource usage pattern that does not peak above the need to use more than four skilled people.

This was easy for this project because of the considerable amount of float available in many of the tasks for the pilots' building. So some tasks have been delayed to remove the impossible peaks and fill some of the unsatisfactory troughs.

Because no task has been delayed beyond its total float, this has not generally affected the time planned to complete the project, which can still be done in 89 working days. However, the project manager did decide to remove one small pimple at day 79 by deciding to install the signs on day 80. So removing that tiny pimple has delayed the project finish by one day.

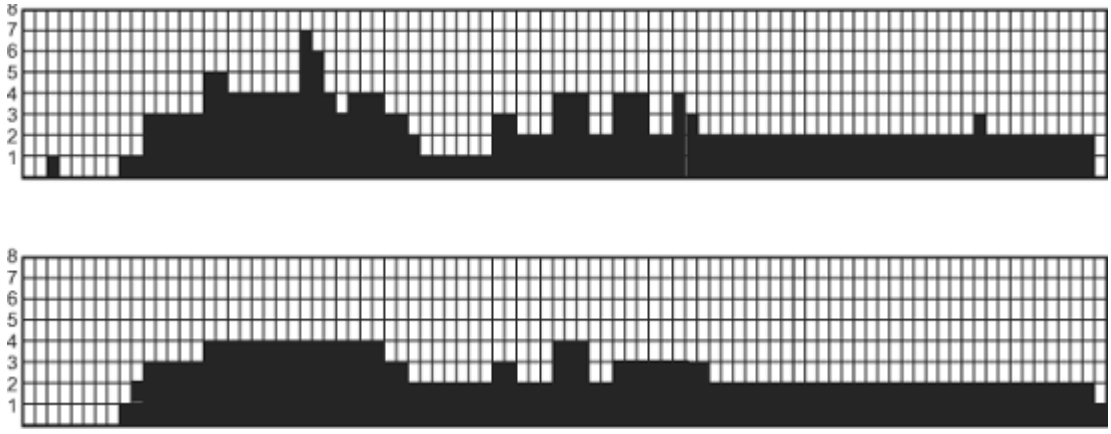


Figure 15.3 Skilled resources for the Sheep Island project before and after scheduling

This Gantt chart method and its result would be acceptable for this project and no more advanced resource scheduling process need be contemplated. However, this project had only 43 tasks and only one scarce resource type. Most aviation projects have far more tasks and more resource types. Further, even this small project would pose problems if project changes or work problems made rescheduling necessary. So for all practical purposes, aviation projects must be planned and resource-scheduled using a computer.

Using a different case example, we shall give an example of more advanced scheduling methods in the following chapter. But before that we need to explain and understand some more of the underlying principles of resource scheduling, and for that purpose we can stay on Sheep Island.

TIME-LIMITED AND RESOURCE-LIMITED SCHEDULES

The planned duration of the project on Sheep Island was 79 days before considering resource scheduling. Even after leveling the resources, it would still be possible to finish the heliport buildings in 79 working days (which is about 16 weeks) provided that no worker fell ill. But suppose the schedule needed six skilled people at peak times to finish the project on time. Then the project manager has a dilemma. Either find two more skilled people or plan for a longer duration.

If the planner decided to hire the additional two people from the mainland so that the project could be finished in its shortest possible time (as derived from critical path analysis), the resource schedule would still have to be

leveled (smoothed) to iron out the peaks and troughs but a peak load of six skilled people would have to be accepted.

The project manager's alternative decision would be to say 'No way can we employ more people, so the project will have to take as long as it takes'. Again the schedule would need to be smoothed, but the scheduled time would have to slip out beyond the shortest possible time indicated by the network diagram. Now the upper resource limits would be satisfied, but only at the expense of a later finish.

All the best computer scheduling programs will give the project manager the option of choosing between these two alternatives. Either stipulate that the resource levels may not be exceeded (a resource-limited schedule) or allow the computer to plan for resource overloads but keep the project within its shortest possible time (a time-limited schedule).

These two options are illustrated in Figure 15.4, where the project is represented as a balloon filled with an incompressible liquid, bounded by the conflicting resource and time limits. Squeeze the balloon down to satisfy the resource limit and something has to give way, so the balloon expands sideways to overflow the time available for the project. Conversely try to compress the project within its time limits and more resources must be found.

Threshold Resource Limits

Some computer programs will allow the project manager to define a threshold resource limit. This is a kind of reserve fuel tank for the project that will allow additional resources to be found at times of peak requirement. The peak resources might be provided by hiring agency or other temporary staff, or perhaps overtime could be allowed for the existing workers. Bear in mind that building overtime into a project schedule is always a bad idea for at least two good reasons:

1. People who habitually work long hours become chronically fatigued. Their motivation and their working efficiency will suffer if significant overtime hours are worked for more than a few days.
2. Overtime should be regarded as a reserve resource, to be held back and not scheduled, so that the possibility of using it is there when unforeseen emergencies arise. And one thing that we can certainly foresee in aviation

projects is that unforeseen emergencies will arise. We just can't say when or where.

THE SIGNIFICANCE OF FLOAT IN RESOURCE SCHEDULING

Although resource scheduling has been possible using Gantt charts for about 100 years, it was only with the joint advent of critical path networks and digital computers that complex resource scheduling problems could be solved easily. All resource scheduling depends in some way or another on being able to adjust the timing of tasks so as to smooth out unwanted resource load peaks. This can only be done without detriment to completing the project on time if time analysis has been carried out, with critical tasks identified and the float available to all other tasks calculated. This was demonstrated to some extent in the Sheep Island project. Now we need to conclude this chapter by gaining a more comprehensive view of how float can affect tasks.

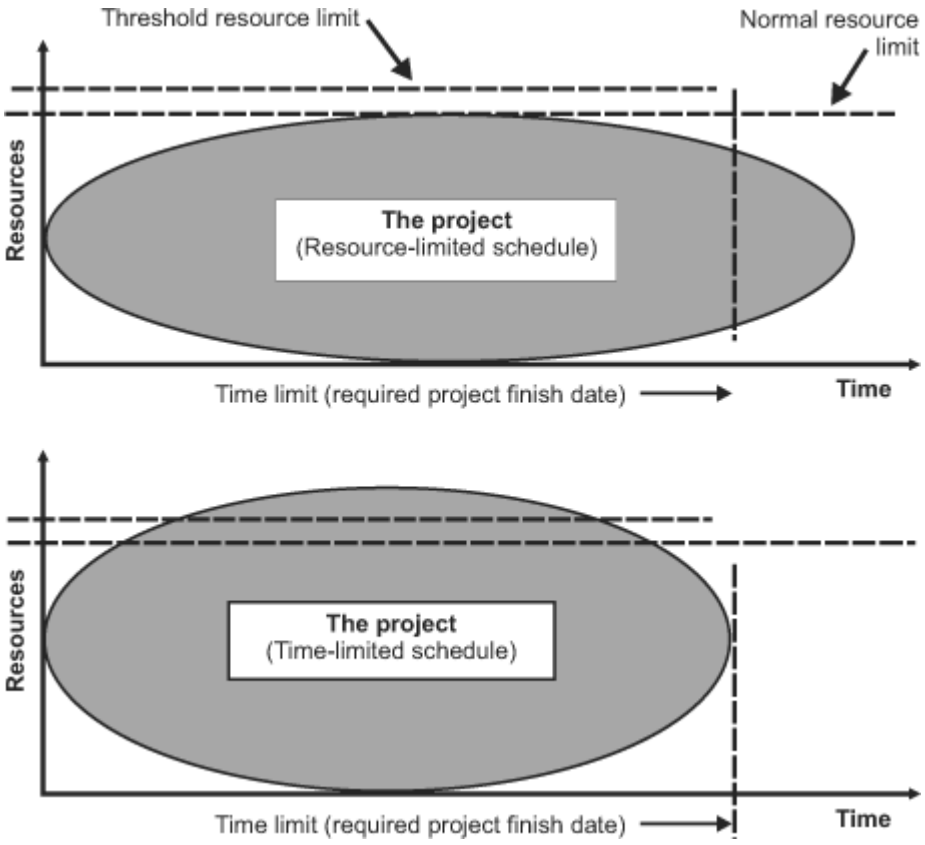


Figure 15.4 Time-limited versus resource-limited priority rules

Think of a string of tasks along a path in a network. Suppose that all these tasks (that is, the network path itself) has a total float of ten days. Fine. We can delay any task in that path by up to ten days, either by accident if the job runs late, or by design to smooth the resource usage pattern. But, importantly, once we delay one task in that path by even one day, we have reduced the float remaining in all the following tasks along that path.

Clearly this knock-on effect becomes more complex when a task is situated in a network, rather than on a single path. Fortunately, the originators of the critical path method realized this problem and as a result have identified and defined four different kinds of float, which we shall now describe to end this chapter.

The Four Different Types of Float

There is more than one way of defining each kind of float, and the definitions vary slightly between arrow networks and precedence diagrams. We give below definitions that are commonly used for the precedence system. We shall use a small fragment from the Sheep Island Heliport network diagram to illustrate these definitions (Figure 15.5). Tasks 25, 26, 27, 30 and 31 in this network fragment clearly have zero float and are critical. In other words they lie on the critical path. They have no float of any kind.

Total Float

Total float is defined as the amount by which a task can be delayed if all its preceding tasks take place at their earliest possible times and following tasks can be allowed to wait until their latest permissible times.

For example, the time analysis data for task 29 (build entrance ramp) show that although it could finish on day 27 that finish could be delayed until day 89 without delaying the project. Its total float is thus 89 minus 27, which is 62 days. Task 40, install doors, could finish on day 47, but that finish could be delayed to finish on day 69 without delaying project completion. Its total float is therefore 69 minus 47, which is 22 days.

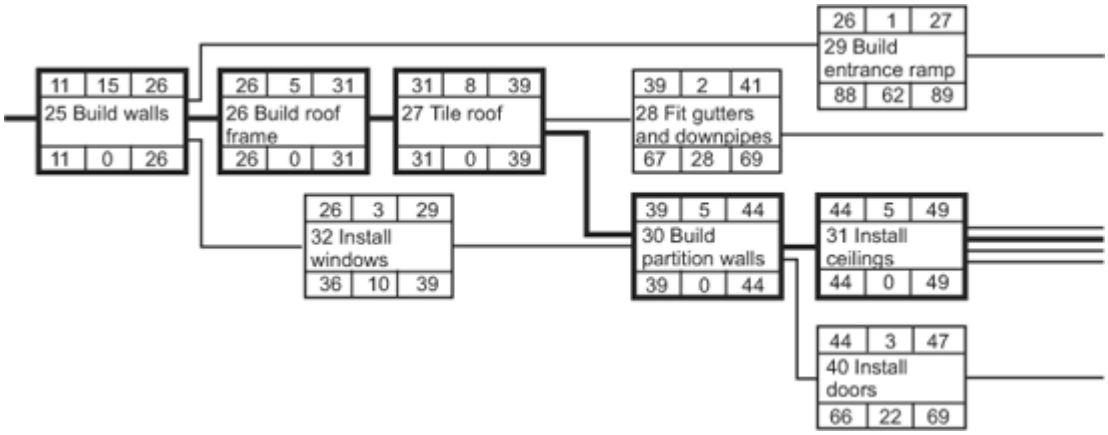


Figure 15.5 A fragment of the network diagram for the Sheep Island Heliport project

Free Float

Free float is less common than total float and is defined as the amount by which a task can be delayed if its preceding tasks take place at their earliest possible times and the immediately following task can still take place at its earliest possible time. There is one example of this in Figure 15.5, at Task 32, install windows. First, note that total float of this task is 10 days and this result is written in the activity box. However, because of the network configuration, should this task be delayed by any amount up to 10 days the immediately following task (Task 30) can still take place at its earliest possible time (it can still start on day 39). Thus Task 32 has free float of 10 days. In this case the free float happens to equal the task's total float, but that is by no means always the case.

We cannot tell from this network fragment whether or not tasks 29 or 40 have any free float because their immediately following tasks do not appear in the illustration. However, turn back to Figure 13.9 and look at task 35, cover fuel tank. That task could be delayed by two days without affecting its immediately following task 41 and it therefore has two days free float (which is correctly given in the tabulation at Figure 13.10).

One way of calculating free float is to take the earliest start of the immediately following activity and subtract the earliest possible finish of the task under consideration. For task 35 in Figure 13.9 we get 36 minus 34, which gives the two days free float result.

Independent Float

Independent float is uncommon, and most project management software programs do not report it. It is the amount of float left to a task when all immediately preceding tasks are delayed to their latest times and the immediately following tasks can still take place at their earliest times.

There is one example of a task with independent float in Figure 15.5. This is task 32, install windows. Even if preceding task 25 takes place at its latest possible time (day 26) task 32 can be delayed by up to 10 days (to its latest permissible finish) without affecting the earliest possible start time of the following task 30.

It is by pure chance that we have chosen a task where the total float, free float and independent float are all equal at 10 days.

Remaining Float

The total float possessed by any task is at risk of erosion from the moment that project resource scheduling starts right up to the time when the task is actually completed. Total float can be reduced, for example, as a result of a conscious decision to delay the planned start of a task as part of the resource scheduling process. There is also the risk that preceding tasks will run late, absorbing some or all of the total float previously possessed by the current task.

For practical purposes, once a project is started the project manager is not interested in the total float that a task had in the beginning of the project, when the network was first drawn. It is the residue of the total float still possessed by each uncompleted task that should concern the project manager. This is the remaining float. Not many software applications can report remaining float, at least not under that title.

Tasks with Zero Remaining Float

Tasks which have zero remaining float have become critical tasks. They should claim priority for resources and for management attention to ensure that they are finished without delay. Otherwise the project completion must itself be delayed.

Tasks with Negative Float

A task can acquire negative float if a target completion date is imposed on a project that is earlier than the earliest possible time predicted by time analysis. For example, suppose that time analysis predicts a completion day of 1 June but the project manager has demanded completion by 28 May. If 28 May has been placed on the last task in the computer as a target finish, then it must drive all critical path values into negative territory.

Implications for Resource Scheduling

Clearly all these different kinds of float have implications when attempting to delay tasks to smooth resource usage patterns. Any planner attempting to use a Gantt chart for this purpose is faced with an impossible mental problem, trying to obey all the inter-task constraints and avoid exceeding the float available. A computer is essential, and we shall give a case example in the following chapter.

16
More Advanced Aspects of Resource Scheduling

In the previous chapter the Sheep Island Heliport project showed how time analysis results from a critical path network are an essential precursor to resource scheduling. Scheduling resources mentally with the help of a Gantt chart is a good way of learning the fundamental process, where tasks can be rescheduled within their available float to minimize overloads and idle periods. Manual scheduling with an adjustable Gantt chart is an excellent introduction for the beginner with the appropriate aptitude.

However, the Sheep Island venture had only 43 tasks. Further, it was necessary to schedule only one resource type. Yet even that tiny project was time consuming, fairly difficult to schedule mentally and open to human error. If there had been a change to that project after its start, rescheduling would have been a tedious chore. Typical aviation projects have very many more times the number of tasks experienced on Sheep Island. Also, projects will probably be competing for resources with other projects running concurrently in the same organization.

Fortunately the problems that these more complex situations bring can be solved relatively easily using a suitable computer system, provided that logic and common sense are allowed to prevail. Not only does the use of a computer make the scheduler's job easier, it also allows greater flexibility in the choice of scheduling options and in handling changes. This chapter explains some of these more advanced options.

CHOOSING WHICH RESOURCES TO SCHEDULE

Distinguishing Between Direct and Indirect Staff

In a typical organization it is the direct workers rather than the indirect staff (the management and general administration infrastructure) who have to be

scheduled. For example, suppose that there are 50 people capable of mechanical engineering design in a company's engineering department. Clearly the allocation of their time to project tasks has to be scheduled. However, the time of that department's manager and some senior supervisors will be spread very widely over many different tasks, and often over different projects, so it makes no sense to attempt to pre-allocate their time to individual small tasks. We have seen it tried, but it only leads to unnecessary complication that adds nothing to project control. Managers are generally classed as indirect workers in such situations.

Most indirect workers below management level do not usually need to be scheduled because they are seen as providing a general service to the main project infrastructure. It is clearly unnecessary to schedule the time of secretaries, technical clerks, storekeepers and so on. The roles of these people are clearly indispensable, yet they rarely, if ever, need to be allocated to tasks on a day-by-day basis.

Choice of Resource Categories

Most project management software will allow hundreds of different resource categories to be specified and processed. But the planner who tries to make too much use of this facility will regret it. Network diagrams, schedules and reports become very complicated and difficult to manage if every possible type of resource in the organization is entered in the scheduling process. The computer will probably fail to produce workload levels that are really smooth for every kind of resource for the very good reason that no perfect solution actually exists.

Our approach has always been first to analyze the organization and its working patterns and pick out the mainstream resources on which project work is heavily dependent. It is usually found that projects make particularly heavy demands on one or two groups of people with particular skills or trades. Clearly resource scheduling should begin with them. Sometimes, a particular machine or other facility, such as a test bay, can cause progress bottlenecks and then there is a good case for including that machine or facility in the resource scheduling mix.

Best practice is to begin by scheduling only those resources that are known to be scarce, but be certain to schedule those as well as possible. Provided that the available capacities for all resources throughout the

organization exist in appropriate relative proportions, when the mainstream or key resources are scheduled smoothly, tasks using other resources in the organization will tend to flow smoothly too. This is, of course, a personal and empirical view, but it is based on our own wide experience.

Some readers might not agree with this approach but it always pays to start implementing any new scheduling system as simply as possible. Think big when planning for the future, but start small now. Other resource types can be added to the database later, if that proves to be necessary.

Relationship Between the Project Schedule and Production Control in Manufacturing and Assembly Departments

Methods for the day-to-day allocation of jobs to people and machines in manufacturing plants have been developed over many decades. Those production control systems deal with many more small operations than the far coarser level of task details seen in critical path networks at project level. Their application is always best entrusted to experts in that field, who are the industrial engineers and production controllers. Those people have their own specialized skills and they have available to them software that can integrate all the detailed provisioning of materials and the scheduling of manufacturing operations. They do not need the help or interference of the project manager.

However, every manufacturing work package has to be delivered according to dates derived from the project schedule. Some consideration of overall manufacturing resources often has to be given when scheduling resources at project level.

Every capable project planner will quickly learn the particular characteristics of the organization in which they work, and will adapt their planning and resource scheduling methods to suit. As a general rule, we can say that the job of the project manager vis-à-vis resource scheduling is to ensure that work is released to the manufacturing plant (as sets of drawings and manufacturing instructions) at a general rate that is consistent with the plant's capacity. In projects, these releases usually occur in batches, perhaps in sub-assembly or main assembly sizes, rather than as individual piece parts.

Fortunately, scheduling tasks and their resources from the project network diagram will do a great deal to ensure smooth workloads in the manufacturing plant. That comes about from the fact that all manufacturing

operations for new projects depend on the issue of drawings and specifications from the design department. If the design and drawing office people are scheduled to achieve smooth workloads, then it follows that the drawings issued by them should arrive at the production manager's office in a relatively smooth flow, mostly in batches related to main assemblies and sub-assemblies.

When it is necessary to show greater manufacturing detail in the main project plan, and to attempt some kind of resource scheduling for manufacturing tasks, we suggest that the project planners and production controllers need to meet and discuss solutions that will satisfy the need to maintain manufacturing workloads at a steady pace whilst not overburdening the main project plan with manufacturing task details. For example, in one case from our own experience we were able to achieve adequate scheduling of the manufacturing resources simply by adding tasks to the network diagram for light machining, heavy machining and assembly (for each sub-assembly). Clearly every organization will have its own characteristics and, therefore, its own solution.

Planning and Scheduling Resources in External Sub-organizations of the Project

No sane project manager would attempt to schedule resources that are outside the control of the main project company. Obviously sub-contractors and external partners will be expected to schedule their own internal resources.

However, that does not mean that a project manager should necessarily have no interest in the internal planning and resource scheduling methods used in those external organizations. Some external companies might have insufficient planning and scheduling expertise or experience within their own walls to carry out planning and scheduling effectively. The main project manager should be willing to offer guidance to such external organizations (provided it is accepted), because doing so can only benefit the project and its outcome.

In some cases, especially where a government department is providing project funds, there might be a contractual requirement for all contractors to use planning and scheduling methods that have the investor's approval.

Another consideration is where the project manager is operating a web-based system of progress reporting and control and in such cases it is important that all the methods used by the various key sub-organizations are compatible with the main contractor's software. This is often achieved by exporting every individual company's data to universally popular software (which means Microsoft Project). Most competent systems will allow this (Open Plan Professional, with which we processed the case example at the end of this chapter, will certainly feed data to Microsoft Project if required).

SPECIFYING RESOURCE AVAILABILITY LEVELS

For each category of resource to be scheduled, the computer system will expect the project planner to enter a resource identifier code, plus the numbers of that resource available for scheduling and the cost rate for each resource unit. Different software suites have their own capabilities and requirements.

The resource input form on the computer will undoubtedly ask for beginning and end dates over which the declared availability for each type of resource will apply. Most programs will allow several different date ranges to be specified, which gives the planner the opportunity of specifying resource availability levels in the future that allow for possible recruitments or downsizing.

Now comes a serious dilemma. Taking an engineering design department as an example, the planner might know, for example, that there are 50 qualified people in the department but, at any given time, some will be on vacation, others will be absent through sickness, and still others might be away on training courses or conferences. Of those that remain, many more might be engaged on work for other projects, unless the whole organization is one dedicated project team. The complexity does not end there, because in any group of workpeople it is highly possible that some of them will be carrying out re-work (sometimes called after-issue work). Also, non-scheduled jobs frequently crop up in many organizations, for example in answering unexpected requests from valued customers or performing other miscellaneous tasks. An idea of this complexity is conveyed in Figure 16.1.

Before the advent of computers, planners were often asked by managers to compile charts similar to that shown in Figure 16.1, usually with color-coded blocks to represent different clients or different projects. Needless to say,

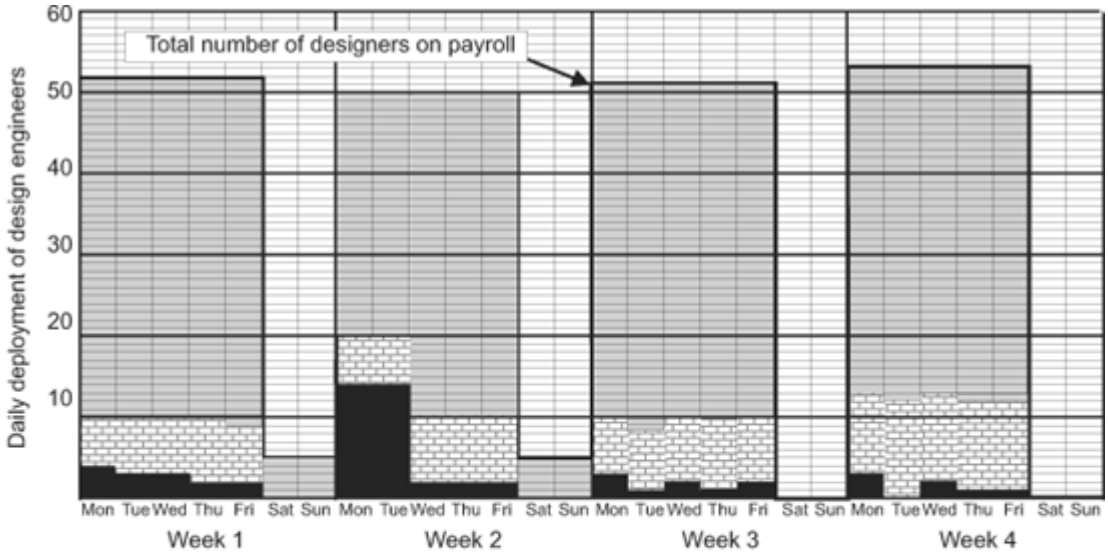
although such charts might be effective when giving presentations to senior management they quickly become out of date. They are not the best possible tool for planning staff levels (even though that was once the only method available to us). When used to show company-wide resources, manually produced charts are clearly inflexible and difficult to compile. But, with a computer such scheduling problems are relatively easier to solve provided that two logical processes are followed:

1. If there is more than one project alive in the company, all projects must be resource-scheduled together in one combined calculation. This is far simpler to do than it sounds provided that a suitable computer system is in use. This process, called multi-project scheduling (a branch of program management) will be described later in this chapter. Anyone who can schedule a single project will find the step up to multi-project scheduling very easy to make.
2. Do not declare the full complement of people as being available for work on projects. Thus, instead of declaring all people on the payroll as being the available resource, give a lower quantity. In our experience we often found that setting aside 15 per cent of a resource will deal adequately with what we might call the sludge factor. In the case of the 50-strong engineering department mentioned above and illustrated in Figure 16.1, this would mean declaring only 42 designers as being available for work on all current projects.

SPECIFYING COST RATES FOR LABOR AND MATERIALS

If resource costs are to be scheduled along with resource usage, the planner will be expected to enter a cost rate for each resource. The methods for doing this differ from one program to the next, and even with a program there might be several options. For example, a total cost can be input for a task rather than attaching costs to the resource usage rate. Placing a cost on a task is a useful way of entering the estimated costs of materials. Expected resource costs can be included in that total task cost, or they can be dealt with separately and additionally by specifying a rate for the resource which will be calculated by the computer as a spin-off from resource scheduling.

It should always be possible to specify a standard cost rate per unit of resource per hour. In other cases the standard units of duration used throughout the network diagram are often used. A common approach (our preference) is to specify a cost rate in dollars per each unit of resource per each whole day.


Total number of designers on payroll
Daily deployment of design engineers
60
50
40
30
20
10
Mon Tue Wed Thu Fri Sat Sun Mon Tue Wed Thu Fri Sat Sun Mon Tue Wed Thu Fri Sat Sun Mon Tue Wed Thu Fri Sat Sun
Week 1
Week 2
Week 3
Week 4

Notes:

1. The department strength was reduced when two designers resigned at the end of week 1
2. One new designer joined the department at the beginning of week 3
3. Two more designers joined at the beginning of week 4
4. Designers not present for any reason are denoted thus:
5. There was an aviation conference in Seattle on Monday and Tuesday of week 2
6. Designers working on unscheduled tasks are indicated thus:
7. Designers working on six concurrent projects are shown thus:
8. Five designers worked on high-priority tasks over the weekends of weeks 1 and 2

Figure 16.1 Resource usage during four weeks in the life of a design department

ALLOCATING RESOURCE QUANTITIES TO TASKS

Whenever resources are scheduled, it is necessary to choose suitable numerical units to define the quantities. Simple numbers can usually be used to quantify people within a special skills group or from a particular department. If 50 fitters are free for allocation to the project, then 50 resource units are entered in the system as the available strength. If eight of those fitters are required to work on a single activity, this might be indicated

on the network, computer input and subsequent schedules as 8F (where ‘F’ or some other suitable code identifies the resource as fitters).

An activity might have two, three or many more different types of resource assigned to it. This will be demonstrated in the case example at the end of this chapter.

Decimal Resource Quantities

There are occasions when one or more people working on a project might have to spread their working day over different tasks. This is not true in most departments but consider, for instance, the buyers in a purchasing department. An average purchasing activity might only involve each buyer intermittently, because most buyers handle several inquiries and orders at the same time. It is not usually necessary to schedule the work of purchasing departments but some large projects can impose a heavy and uneven purchasing workload. Then the planner might decide that some way must be found to allocate buyers part time to activities so that project purchasing can take place in the correct sequence of priorities without causing health-threatening overloads.

In general we do not recommend attempting to schedule resources in such fine detail that decimal quantities have to be specified. If it is considered unavoidable it can usually be done by breaking task durations down into hours rather than days.

Some project management software will accept decimal resource quantities, but others will not. Sometimes it is necessary to resort to tricks. Taking a buying department as an example, if a buyer typically works on 10 different purchasing tasks in one day, the planner might want to call the resource usage for each task as 0.1 buyers. But if the software will only accept whole numbers the planner can factor the units, simply by multiplying everything by 10. Then if two buyers are available, these are declared as 20 buyers, and an actual task requirement of 0.1 buyer would be stated as one buyer. We have used such tricks ourselves, but we cannot recommend them. It is best to avoid unnecessary complication and begin by scheduling only the mainstream resources.

If artificially factored resource units are used, any cost rate specified for the resource must be divided by the same factor so that cost reports will be corrected to counteract the large quantities created artificially by the factoring trick. Once again quoting the buyers, suppose that the standard cost

rate for one buyer is $150 per day and that days have been used as the standard duration units on the network. Because the units have been factored by 10, the standard daily cost rate for ‘one buyer’ (which in this distorted case would actually mean 0.1 buyers) must be specified as $15.

If a planner really cannot avoid or resist going into decimal resource quantities, the best solution is to use software that will accept them. Some programs will allow resources to be specified in terms of work-hours, both as the daily requirement and as the availability. This is allowed even when the activity durations are estimated in days. Then the planner can specify a resource being assigned to a task for fewer than the full eight hours normally occupied by a day.

SCHEDULING MORE COMPLEX TASKS

Tasks With Non-linear Resource Needs

In the Sheep Island Heliport project we assumed that every task could be estimated in terms of its duration, (measured in days in that case), during which time the specified resources would work at a uniform rate. Thus a task of 10 days requiring two skilled people meant two people working on the task every day (giving a total work content of 20 labor-days). In project management parlance that is called constant rate resource usage.

Some planners become concerned that their project has tasks where the resource usage is not constant. Figure 16.2 gives an example. The more competent computer packages will allow planners to specify such non-constant usage. However, we do not consider that to be necessary, for the following reason. In a typical project, there will be many tasks taking place at the same time, all using resources from the pool. In our view, provided that the overall rate of working has been scheduled to use the average number of resources available, fluctuations within individual tasks will be smoothed out. In other words, they will only be small ripples in the larger resource ocean. In any case, remember that everything in the schedule is based only on estimates, and estimates are never precise. Thus we recommend remaining with the default, simpler option of rate constancy. That is the commonsense approach. Never complicate a schedule with complex input where that is not justified.

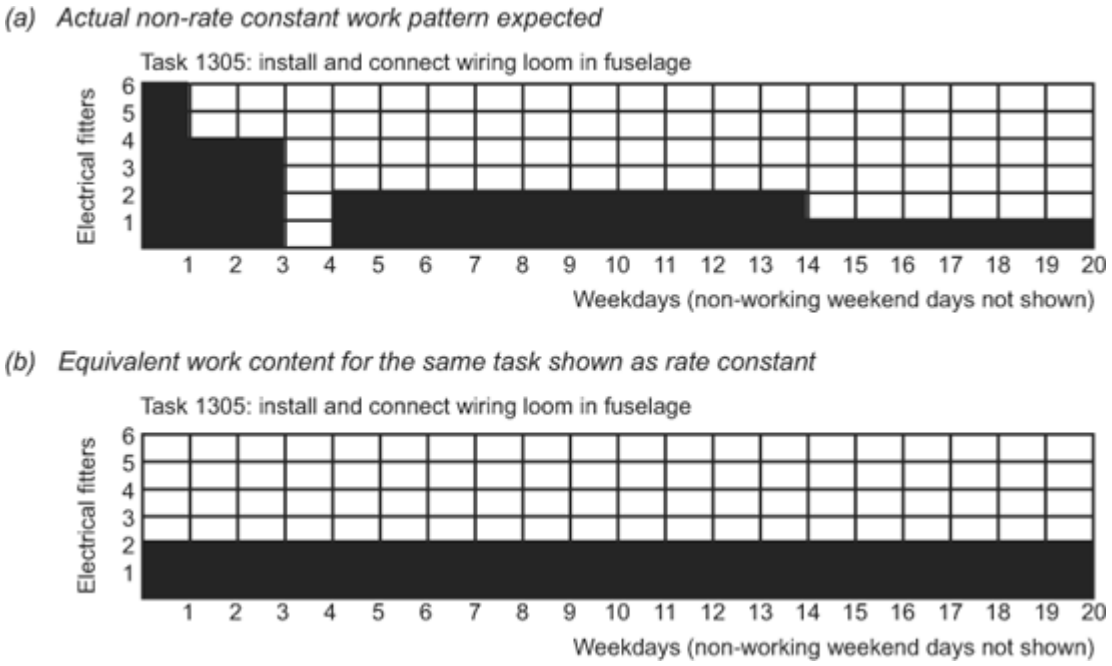

(a) Actual non-rate constant work pattern expected
Task 1305: install and connect wiring loom in fuselage
Electrical fitters
6
5
4
3
2
1
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Weekdays (non-working weekend days not shown)
(b) Equivalent work content for the same task shown as rate constant
Task 1305: install and connect wiring loom in fuselage
Electrical fitters
6
5
4
3
2
1
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Weekdays (non-working weekend days not shown)

Figure 16.2 A task with non-rate constant resource expectation

Splittable Tasks

Most computer software will allow the planner to make an advance choice when inputting the information for each task from a network diagram as to whether or not the task is splittable. A splittable task can be planned to stop and restart later to allow scarce resources to be diverted temporarily to another task that has less float. All good software should assume that every task is non-splittable as the default condition. Thus no task will be scheduled with gaps unless the planner has specifically 'given the computer permission' to do so. We cannot generally endorse the practice of splitting activities because of the demotivating effect that this will have on the workers affected. Further, leaving work on one task to go and do work on another might be fine in theory, but in practice it will be less satisfactory because each worker has to try to remember the condition of the split task when it was temporarily abandoned and it might not always be easy to pick up the pieces. However, although we have never used this facility ourselves, we can see that it might have some merit in tasks of very long duration.

Planners must ensure that the software in use does not allow splitting as a default condition. We believe that at least one program does have this trap.

USING DIFFERENT CALENDARS

All project management software will have an inbuilt calendar that recognizes calendar dates over very many years—past, present and future.

Adapting the Default Calendar for Tasks Carried out in the Home Office or Local Plant

The computer and its project management software will undoubtedly offer the project planner a calendar for general project scheduling. This is the calendar that will convert the day numbers obtained from time analysis to actual dates, depending on how many days are to be worked in each week. The most usual default calendar is a working week of five days, which in the Western world means Monday through Friday. Of course, for this to happen it is necessary for the planner to specify the start date, which is often done on the input record for the first task.

Many calendars specify the time of day too, and the default condition in those cases might be from 09.00 to 17.00 daily. One popular program uses an eight-hour day split into two halves, from 08.00-12.00 noon and from 13.00-17.00.

Thus in the default calendar five days will be equivalent to one calendar week, with nights and weekends simply not available for scheduling any task. Whenever a new task record is added to the computer, it will usually be assigned automatically to the default calendar, but the person entering the data will have the opportunity to specify and assign a special calendar instead.

Incidentally, it should be noted that as far as the computer is concerned, close of work on one day (say a Monday night) is the same instant in time as the start of work on the following day (Tuesday morning) because to the computer the intervening night hours simply do not exist because they are not in the calendar. Similarly, and more spectacularly, close of work on Friday night is regarded as the same instant in time as the beginning of the working day on the following Monday.

All good software will allow the scheduler to modify the default calendar, for example by declaring forthcoming public holiday dates as non-working days.

Setting Up Special Calendars

An arrangement possessed by all good project management software is to allow the scheduler to set up one or more special calendars. It is usually possible to set up hundreds of these, although in practice only one or two might be needed.

Special calendars for countries or states with different public holidays and working hours An international aviation project will have people working in different offices and plants around the world, and not all of those countries will have the same working week as that which applies to the main contractor's home office. A project managed from an office in the US will probably have a main working calendar that operates from Mondays through Fridays. But if that contractor has associated companies, partners or groups of employees working in some Eastern countries it is more likely that their working weeks will run from Sunday through Thursday.

If the network diagram has a mix of tasks that uses different working hours for any reason, the simple solution is to create a special calendar for each location and assign the appropriate calendar to each task at the time when it is entered as a record into the system. Even within the US, special calendars may be needed because different states observe their own festivals and non-working days.

Weekend and shift working It sometimes happens that a schedule must allow for a mix of single shift (normal) working with two- or three-shift working. Perhaps all the office staff, including design engineers, work five days in a week and some workers in the manufacturing and assembly plants work two or three shifts within each 24-hour period. This can complicate planning and scheduling somewhat. Matters will be even more complicated if some, but not all, people normally work over weekends.

All these problems can be overcome by setting up and using special calendars. Any task that requires resources during times not allowed for in the five-day week default calendar can then be assigned to its appropriate calendar, specially created for the purpose.

One calendar might, for example, allow two-shifts per day from Monday to Saturday (inclusive). Another might allow three-shift working for seven days each week.

A full seven-day calendar should, strictly speaking, be applied to passive tasks, such as waiting for concrete to set or for paint to dry. Naturally concrete will continue to set and paint will keep on drying throughout non-working days. However, most people find that they can cope with the default five-day calendar and ignore this apparent problem.

There are some advanced programs that will allow special calendars to be associated instead with resource categories as well as with tasks.

Holidays

There are two fundamentally different kinds of holidays to cater for in project scheduling:

1. **Personal holidays**—absences of individual people for vacation days taken from their personal annual entitlement, for compassionate leave, for training or for any other special reason.
2. **Organizational holidays**—times during which no work on the project can take place. These include public holidays and other periods when all the offices and manufacturing plants are shut down.

Scheduling personal holidays Unless the individual concerned is the only person in a particular resource category (which would be very unusual) the simplest, most convenient and acceptable way of dealing with individual absences for any reason is to include personal absence times in the sludge factor that was mentioned earlier in this chapter (Figure 16.1). In other words, the general availability of the resource category is purposely understated to take account of the fact that, at any given time, a certain percentage of that resource will be absent or otherwise unavailable for project work.

Scheduling organizational holidays General public holidays and annual plant shutdowns are dealt with by specifying the relevant days as non-working days in the default calendar. In international projects, where project tasks are spread over a number of different countries, each country will have its own set of public holidays. Some countries will even have different workings days in each week. This apparent difficulty is easily overcome, as mentioned earlier in the section on calendars, by creating a special calendar

for each different country. Then tasks to be carried out within those countries must have the relevant calendar assigned to them.

MULTI-PROJECT SCHEDULING

In organizations which conduct several projects concurrently, resource scheduling of one project on its own is made more difficult by the knowledge that other projects will be using common resources and so will deplete the availability of resources for the single, subject project. The solution is to schedule all concurrent projects simultaneously, so that they all draw down resources from the total company availability. This may sound like a big bold step for the novice planner to take, but actually multi-project scheduling is easier than attempting to schedule a single project. Although all the numbers are greater, the planner does not have to make the impossible choice of knowing what proportion of any total resource should be allocated to a single project.

The application is far simpler than one might expect. Each project becomes a sub-project of the total projects model. A required beginning and end date must be specified for each 'sub-project'. Every project (or rather, sub-project) must be represented in the multi-project model by its own sufficiently detailed network diagram. Then the computer is able to calculate the float for every task in the model, and allocate resources accordingly from the common pool.

Now priorities between different projects, not only separate tasks, will be taken into account automatically by the software. Those priorities will be driven initially by the target start dates specified for each project. Time analysis of all the projects in the multi-project model will assign a total float level to every task. That will automatically ensure that projects are worked through in their correct sequence.

By coding tasks and sub-projects the computer will be able to sort data and filter it so that departmental managers get work-to lists that are specific for all project tasks within their own responsibilities. The method is very powerful and simple to operate provided rules are kept simple and over-complication is avoided.

Senior management, sales managers and individual project managers will undoubtedly have views on priority differences between all the sub-projects

in the model. There are occasions, for example, when one customer might be regarded as being more important than another. There is then a risk of senior managers attempting to interfere with the scheduling process, with a desire to force the progress of one or two projects at the expense of others. If the project planner cannot overcome these undesirable external influences, the favored sub-project will have to be given some form of higher priority by artificial means. This can be achieved by placing an artificially early target completion date on the final task in the relevant sub-project.

A multi-project schedule has benefits for an organization beyond the planning and control of existing work. The schedule, if properly prepared, is a model of a company's total workload. As such, it becomes a powerful aid to manpower and corporate planning. It is possible to run 'What if?' trial schedules, testing possible new projects in the multi-project model to see what effect these might have on the company's future workload and capacity requirements.

Risk of Duplicated Task Numbers in the Multi-project Model

There is a probability that the same task identifying code numbers will appear in different sub-project networks within the multi-project model. This will be true particularly if the tasks for each sub-project are numbered in a simple numeric series. With some software this can be disastrous. When presented with two or more sub-projects containing duplicated numbers, the computer sees the whole conglomeration of data as one huge error-laden network. There are several possible solutions to this problem, which depend largely on the capabilities of the software chosen.

One solution is to ensure that duplicate numbers can never arise between different sub-networks. A good way to prevent duplication is to prefix all the task ID codes within each sub-project with a unique string of characters. The length of this string will obviously depend on the number of sub-projects to be managed, but it is unlikely to be more than two or three characters. Some software can add such prefixes automatically across all the tasks in a sub-project network. Project ID numbers, or parts of them, can provide useful and logical prefixes. It is, however, too easy to build up very long task ID codes, which are best avoided because they increase work and the risk of human errors. Some of the cheaper software systems can only accept ID

codes containing perhaps four or six characters in total, which does not allow much space for a prefix.

Fortunately, most software packages do not demand that every number in the overall multi-project model is unique. It is only necessary to make certain that every identifier is unique within its own sub-project network diagram.

Interface Tasks (Activities) in Multi-project Scheduling

There may be a few instances where it is necessary for one or more sub-project networks to share the same task or have a linking constraint. In such cases the common tasks must bear the same identifier, and be designated as interface tasks. Interfaces are highlighted on network diagrams by enclosing the task box with a double-ruled border.

The incidence of interfaces in multi-project scheduling should be rare. It is not good practice, for example, to use them in an attempt to force priorities between different sub-projects (where reliance on remaining float relative to scheduled target dates is by far the more sensible option). One situation where interfaces can be used relates to shared assembly space, as mentioned in the following section.

Scheduling Assembly Space that is Common to All Projects

Multi-project scheduling becomes difficult in the allocation of space in assembly hangars. Clearly the assembly of one new prototype aircraft cannot be started until the plane from the previous project has been assembled and towed away from the space needed.

The total assembly space itself can be difficult to schedule using project management programs, especially when the project mix includes aircraft of very different sizes. Scheduling by simple units of area is not sufficient because that ignores the important three-dimensional space dimensions. The sequence in which different projects arrive in the assembly hangar can be indicated by a trial run of the multi-project model, but the actual allocation of assembly space have will have to be decided by the project planners in conjunction with the assembly managers. The assembly managers will have their own methods for scheduling space, for which engineering design software is one obvious solution.

There must be some way of feeding back decisions on the allocation of assembly space into the multi-project model. Planners with sufficient skills soon learn how to use tricks to force the software to do what is needed. We can suggest two different solutions. One method is to impose scheduled dates of the 'not-before' variety on the first main assembly task in each different project network. A more flexible way is to introduce links between the assembly start and finish tasks in the different projects, which can be done by declaring relevant tasks as interface tasks. Then the computer will 'see' each interface as a task common to two or more projects. All this depends on the capabilities of the software being used and on the skill and ingenuity of the planners.

ADMINISTRATION OF THE MULTI-PROJECT MODEL

The multi-project model can be expected to have a continuous but constantly changing existence. It will comprise a variable number of sub-projects, each with its own different finite life. At regular or irregular intervals, new projects must be added, completed projects removed and progress information or other changes injected for current projects. Managing such a model can be a formidable (but worthwhile) task. Even though individual project networks might be of manageable size, perhaps containing only one or two hundred tasks, the total multi-project model for even a medium-sized company might have 20 000 or more tasks.

Strict attention to data preparation, system security and updating disciplines must be observed if the whole model is to be maintained in a viable state. This usually means that access levels to the system must be carefully controlled, through entry passwords. Certainly the data should be accessible for all authorized people to view, but only those with the necessary training and skills should be allowed to enter data or commands that could materially affect the project files and the resulting schedules. Access that can change the system parameters must be even more jealously guarded. Figure 16.3 shows the arrangement that we favor for maintaining the integrity of the multi-project model, while still allowing adequate access for the system users.

The coordination function need not be expensive. Training and hands-on experience must, however, be given to at least one key planner and one or

more deputies. In larger organizations the logical and ideal home for administering the multi-project model is the project support office.

Issue of Departmental Work-to Lists

With the increased amount of data stored in the multi-project model, even more careful thought has to be given to the OBS as it is arranged within the computer. This is essential for ensuring that data can be properly filtered to give departmental managers reports that contain only information that is personally relevant, interesting and useful to them and their own departments.

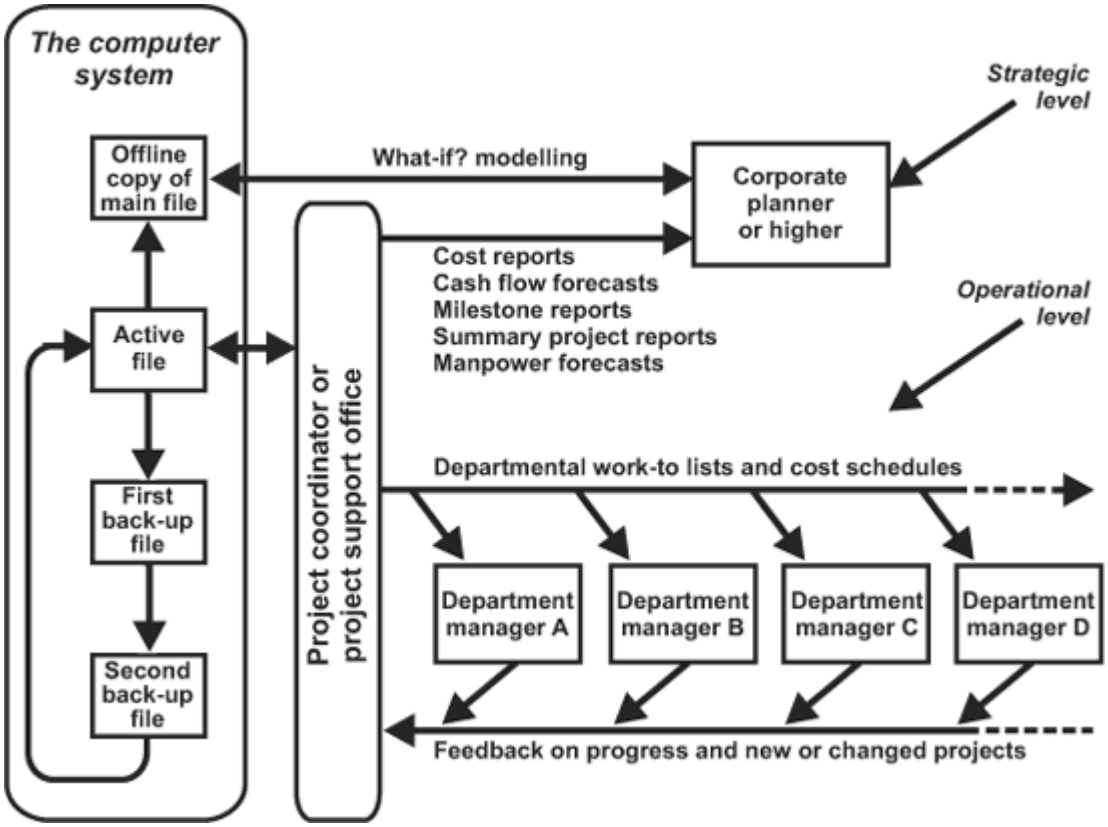


Figure 16.3 Managing a multi-project model
The integrity of the model must be preserved. This can be achieved by allowing access for system changes only through an expert person or group such as a project support office.

Perhaps the most valuable reports for the purpose of getting project work done on time are the departmental work-to lists produced from the resource scheduling process. Whether these are from a multi-project schedule or not, they give each departmental manager or specialist group a dated list of all the

tasks for which they are responsible. Tasks for other managers are filtered out and excluded, a process made possible by adding departmental codes from the OBS to all the tasks.

Work-to lists are usually sorted by the computer into ascending order of the scheduled start dates for all the tasks listed. However, other sort sequences are useful in some cases. For example, the expeditors in a purchasing department might like to see all purchasing tasks sorted in ascending order of their finish dates, because expediting is so closely tied with getting goods delivered before those finish dates.

We have already given examples of task list reports produced from time analysis without resource scheduling (Figure 14.4, for instance). However, each work-to list arising from resource scheduling will also give *scheduled* start and finish dates for every task. These scheduled dates are the times when each task should be performed to achieve level resource usage. They recommend when each task should be done. The exhibits in the case example at the end of this chapter are from software that deals with this need very well.

Tasks which are the joint responsibility of two of more managers

Allocation of departmental codes, working group codes, resource codes and task-level codes can all be used to facilitate editing and filtering. A difficulty that sometimes arises concerns tasks which cross boundaries and require resources simultaneously from more than one department. One example is from an engineering company where prototype manufactured assemblies are subjected to testing that has to be performed by one department and witnessed by another. How can the system be made to produce a report containing the same prototype test tasks for each of the two managers concerned without including nonrelevant tasks?

One answer in this particular case is to filter the reports according to the resource codes. Tasks using two or more resource types would simply appear in the corresponding number of reports. Where tasks involve two separate departments but use no significant resources, there is a simple trick. Artificial resources can be created, to allow sorting on their codes. These artificial resources can be given a cost rate of zero and be stated as being available in numbers that cannot possibly constrain resource scheduling. Project resource scheduling is fertile ground for the invention of tricks that will overcome apparent software limitations or other problems.

Updating Intervals for Multi-project Schedules

The increased amount of stored data and the far higher probability of frequent changes in the multi-project model mean that regular updating is mandatory. Updating in this sense means the declaration of a new time-now (start datum from which scheduling begins) and complete reprocessing of all time analysis, resource schedules and cost calculations throughout the model. The frequency of updating will depend on the amount of data and rate of change in the system, but will probably have to be every two or four weeks or calendar monthly.

PROJECT RESOURCE SCHEDULING IN THE CORPORATE CONTEXT

In any organization, planning has to be carried out at several levels. These range from overall, strategic corporate long-range plans to the day-to-day allocation of tasks to individual people and machines. Project scheduling generally lies between these extremes, and can serve several purposes in the general planning context.

Project schedules (combined with sales forecasts of possible work to come) provide the data from which manpower, financial and other long-range corporate plans can be formulated. These data are not needed in great depth of detail. They should instead be summarized in quantities that will suit the broad corporate plans that they feed. This is the ‘upward looking’ purpose of project schedules, for which they should predict departmental manpower and facilities needed, the types of skills required, cash flows and the like. If the organization is a joint venture or other company set up to handle a single large project, there is one level of planning less for the company to do, because the overall project schedule doubles as the corporate plan.

The principal ‘downward looking’ purpose of project schedules is to list the jobs that all departments will have to carry out. These are sometimes known as ‘work-to’ lists. The purpose of these lists is to feed work to all the departments in correct sequence, timed to fit in with project needs. Effective resource scheduling, leading to the issue of work-to lists that are sorted and filtered for the attention of individual managers, should ensure that work is fed to departments at rates that will not cause overloads.

It should then be the job of the departmental managers to arrange the lowest layer of scheduling, which is the day-to-day allocation of jobs to individual people according to their availability or particular aptitudes.

WHAT-IF TESTING USING A MULTI-PROJECT MODEL

Once a multi-project model has been established it is likely to be viewed as fertile ground in which to plant trial projects for 'what-if?' testing.

When a new project opportunity arises, the planner can create a simple summary network to represent the new project and inject it into the multi-project model, carry out complete processing and report back to senior management on the results. There is no need to draw a *detailed* network for each trial sub-project, but there must be sufficient summary tasks on which to load the estimated resources and to produce an approximate timescale if the organization's total capacity is to be tested realistically. Such testing can be invaluable for influencing strategic management decisions.

System security safeguards must be designed when 'what-if?' calculations are anticipated. All 'what-if?' trials must be carried out on a copy of the main multi-project model, not on the working file, so that working schedules and the database cannot be corrupted. Some software will allow 'what-if?' testing to be performed with adequate safety. Others will use the main model so that, when the 'what-if?' test ends, the planner has to delete the trial sub-project, reprocess the multi-project model and hope that the database, the schedules and the work-to lists will all be restored to their pre-test state.

CHOICE OF SOFTWARE

There is a great wealth of software available, much of which is capable of carrying out multi-project resource scheduling over a considerable number of tasks. However, some software will only accept a limited number of sub-projects and is therefore less suitable for multi-project applications.

The most expensive software will not necessarily be the best. But the cheapest software will probably have capabilities that are too limited. Further, popularity of software is no indication of its capabilities. At one time we could have named and recommended a few brands, but now so many are available that we prefer to give more general advice.

Software that is widely available, user friendly and popular may be fine for managers who have no project management training and limited expectations of what the software should do. Some software in that 'popular' category appears to us originally to have been devised by computer specialists without paying adequate attention to the serious needs of expert planners—we get what the IT developers think we need.

One or two 'high-end' products, such as Open Plan Professional and Primavera have been developed over many years with the needs of project planning experts foremost. Another contender in this category is so outrageously overpriced that we have not named it. Other brands such as Micro Planner X-Pert have a long pedigree, traceable back to the pioneering days of planning and scheduling, that should inspire confidence. Unfortunately the best software is not always the most widely sold, and a good example of this is the UK-based 4c Systems product, which is without doubt the best and most versatile product that we have ever encountered, with its origins traceable back to the 1960s and mainframe computers.

Buying new software should be approached in the same way as the purchase of any major company asset because it requires considerable investment. This investment comprises not only the purchase price and maintenance costs, but also the considerable amount of staff time needed to learn how to use the system and enter all the data. Get this wrong, and a second start with different software will be more difficult because people's motivation will have been shot to pieces.

Figure 16.4 is a program capability checklist that we have used in the past, both in our own organizations and when advising clients. Figure 16.5 is a diagrammatic representation of the purchasing process.

There are many differences between operating methods and capabilities of the different project management software products. We strongly recommend that the planning individuals in an organization receive training from the vendor before implementation on projects.

CASE EXAMPLE: THE LOX BROTHERS LIGHT AIRCRAFT DEVELOPMENT PROJECT

The following imaginary case example is necessarily simple, so that it will fit within these pages, yet it contains ample material to allow demonstration

of critical path resource scheduling for a single project.

Two brothers (Jo and Charlie Lox) own a profitable automobile sales and repair business which employs about 75 mechanics and sales staff. Both brothers are keen private flyers and they have a private airstrip attached to their home. They own two light aircraft, which they keep in a large but simple hangar. In a move to diversify their business, the brothers have decided to set up a new company, to be called Lox Brothers Aviation, with the objective of designing and manufacturing a light aircraft for sale to private enthusiasts. Their company will initially be entirely privately owned, with capital invested by themselves and members of their families. In time they hope this venture will develop into a flourishing business offering a range of small aircraft to private flyers.

Item	*Program characteristics*
Environment	• Stand alone only? • Network? (details required)
Ease of use	• Are the drop-down menus helpful? • How good are the help screens? • How good is the documentation provided? • How fast is the expected processing time using: (a) our available hardware? (b) new hardware as recommended?
Activities	• Maximum number of activities possible in one project? • Maximum number of precedence links in one project? • Maximum number of activities possible altogether? • Maximum number of precedence links possible in system? • Maximum number of characters possible in activity ID code? • Can activity ID codes be alphanumeric? • Maximum number of characters in activity description? • Can activities be designated as splittable or non-splittable?
Calendars	• Total calendar time span? • How many different calendars can be specified? • What duration units are possible with these calendars?
Updating	• What progress reporting methods can be used? • Will activities reported as started be at risk of rescheduling?
Reports	• What standard report formats are provided? • What are the standard filtering and sorting facilities? • How good are the graphics? • How fast are the graphics printing speeds? • How easy is it to customize reports? • Will the system meet our needs for (say) the next five years?
Error detection	• How effective are the error search routines? • Are error messages clear and in plain language? • Are loops effectively diagnosed or prevented?

Item	*Program characteristics*
Resources	• Can resource scheduling be performed? • How many different resource types can be specified? • How many characters may we use in each resource identifier code? • Can resources be assigned to groups or departments? • Can threshold resources be specified • Can alternative resources be specified? • Any special resource scheduling features?
Cost data	• Can the program assign an hourly or daily cost rate to each resource? • Can the program use both cost rates and charge-out rates? • Can different rates be specified for overtime or threshold resources? • Can an estimated cost be assigned to an activity? • What tabular cost reports are available? • Can cost/time graphs be produced? • Is there a staff timesheet facility?

Item	*Program characteristics*
Templating	• Does the program allow templating? • How easy is it to edit templates? • Can templates be merged automatically with interface links?
Projects	• How many projects can the system hold? • Maximum number of characters in a project identifier code? • Can project identifiers be alphanumeric? • Can the same activity ID numbers be used again in different projects? • Is multiproject scheduling possible? • Can projects be allocated to groups for multiproject scheduling? • Is what-if? scheduling available to test new project strategies and so on?
Operational aspects	• What hardware is recommended? • Will the software run on our server? • Can the new software communicate with our main database? • Are there security safeguards against unauthorized access? • If so, how many levels of security are provided? • Can we customize these security levels?

Item	*Program characteristics*
System costs	• What is the basic price for a single pc user? • What is the basic price for 5 network users? • What is the basic price for 10 network users? or, how much for our anticipated number of users? • Are any optional extras needed and, if so, at what cost? • How much training will be needed and at what cost? • If training is on our premises, do the training costs include travel, subsistence and accommodation expenses for the trainers? • If timesheet capability is to be used, what is the additional cost likely to be for all our timesheet users? • If we should need any customization, what is the likely scale of charges?
System support	• Is first-year support and maintenance free of charge? • What are the future support and maintenance charges expected? • Does system support include free software upgrades? • Is there a hot-line service for advice and troubleshooting? • At what times is the hot-line accessible: — Normal working hours? — Nights? — Weekends • Are we guaranteed immediate response and not an answering machine? • Was this software developed by the supplier or are they simply agents with less in-depth knowledge of the system? • How many systems have been sold? • How many of those users are in our country? • Is there a users' group? • Is the users' group supported by the software supplier?

Figure 16.4 Checklist for choosing project management software

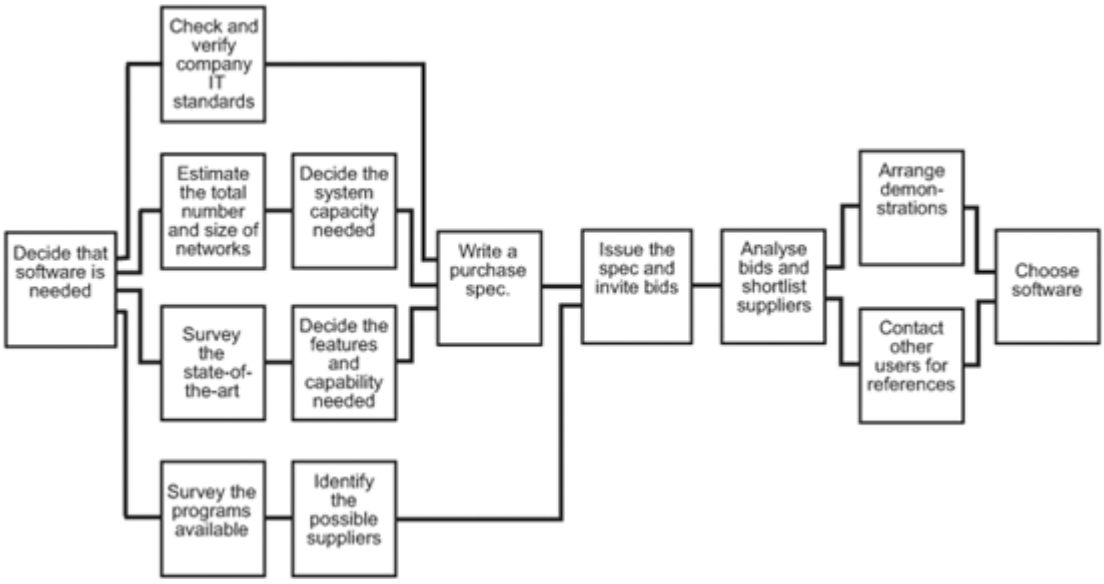

Check and verify company IT standards
Estimate the total number and size of networks
Decide the system capacity needed
Decide that software is needed
Write a purchase spec.
Issue the spec and invite bids
Analyse bids and shortlist suppliers
Arrange demon-strations
Choose software
Survey the state-of-the-art
Decide the features and capability needed
Contact other users for references
Survey the programs available
Identify the possible suppliers

Figure 16.5 Suggested procedure for buying project management software

The brothers plan to install some basic tools in their hangar and they have some limited manufacturing capacity in their car repair workshops. However, they recognize that they will need to enlist the expert help of at least one local engineering company to manufacture some parts, particularly when it comes to some specialist processes such as welding stainless steel. Familiarity with the automobile business means that the brothers hope to be able to adapt some readily available and cheap car parts for use in their first aircraft design (for example in the hydraulics system).

The part of the project with which we are concerned for project planning and resource scheduling includes all the tasks from initial concept to the point where the first prototype is ready for its taxiing trials on the ground.

Initial Design Considerations

For their first venture the brothers plan to design and develop a two-seater, single-engined plane that they will be able to sell at a very competitive price. At first this will be offered in a ready-to-fly version but later they foresee the possibility of selling it in kit form. From the start, therefore, the design must anticipate easy assembly of the plane from its component parts. This means particularly that the fuselage will comprise three bolt-together main sections. The design description that follows is intended to be adequate for project management purposes but we stress that this chapter is not intended in any

way to be a design manual and (because of space restrictions) we have committed the terrible sin of ignoring all the FAA approval steps and procedures that would be needed in practice.

Jo and Charlie have some initial ideas for their first aircraft specification. Square section stainless steel will be used for the airframe, with the fuselage designed as square sided sections. The longerons will extend through the bolted boundaries to add strength. All cross braces will also be of stainless steel but of lighter gauge and smaller cross section. Round section members were rejected because of the difficulty of cutting the tubes for the welded interfaces. The brothers will arrange and supervise the design of the airframe parts, but they will sub-contract manufacture of the frames to a nearby engineering company that has the requisite jigs and welding facilities for stainless steel.

The engine and propeller will be chosen from standard catalogues, with a power rating of between 80 and 100 horsepower. The engine will be nose mounted, and the cowlings will be made from glass fiber reinforced resin.

A high wing monoplane configuration, with supporting diagonal struts, should make construction and design relatively easy and it will also give good ground visibility for the pilot and passenger, who will be able to sit side by side in the small cockpit. All control surfaces will be operated hydraulically, with automobile parts used for the cylinders and reservoirs wherever possible. Flaperons will be used in preference to separate flaps and ailerons.

Particular advance thought has been given to the landing gear and the brothers have already decided to opt for a tricycle arrangement. This configuration means that the aircraft can maintain a level attitude on the ground (similar to a level flight attitude). Many pilots find landings easier with this arrangement, and a nose wheel steered by two rods linked to the rudder bar should make ground maneuvering safer and easier. However, the designer will need to spend some time on the geometry and supports for the nose wheel because of the stresses it will encounter on grass runways. The brothers have in mind a damped coil spring suspension, using automobile components, with the rotatable vertical wheel shaft contained within a tube that is braced with struts from the airframe longerons.

The two main landing wheels will be of aluminum alloy, hydraulically disk braked and enclosed in fiber glass fairings. They will be non-retractable, supported by fixed struts and braces.

Part of the design task will be to select a suitable covering for the airframe and wings, for which a water resistant and rip-proof fabric is envisioned.

Instrumentation will be basic but adequate, and will be conventional, not full glass, grouped in logical clusters on the instrument panel as follows:

1. *Engine:*	Oil temperature gauge, oil pressure gauge, rev. counter (tachometer)
2. *Hydraulics:*	Warning light for low pressure. Warning light for low fluid level
3. *Flight:*	Airspeed indicator, altimeter, attitude indicator, heading indicator, outside air temperature gauge, turn coordinator, vertical speed indicator
4. *Navigation:*	Compass, GPS display, VOR-HSI displays
5. *Fuel:*	Main tank gauges (left and right) with audible low level warning Auxiliary tank gauge with audible low level warning
6. *Avionics:*	Avionics power switch Ground to air radios and controls including microphone holster
7. *Electrical:*	12 volt dc negative ground system. Ammeter to show alternator charging rate, audible warning for low charging rate, switches for navigation lights and cabin lights.
8. *vacuum:*	Vacuum system indicator

Before main manufacture and assembly begins, the brothers intend constructing a flying model to 1/20 of full scale, with radio control, to check out the aerodynamics.

Project Resources

For this project, the brothers can use one or two staff from their automobile business, but they will have to hire some expert designers. To keep initial

costs low, the brothers expect to carry out much of the mechanical assembly themselves. Some aspects of the project, such as the installation of hydraulics and electrical wiring, will be carried out on the assembled fuselage frame, and then recorded and drawn retrospectively. The initial workforce envisioned will comprise the following people:

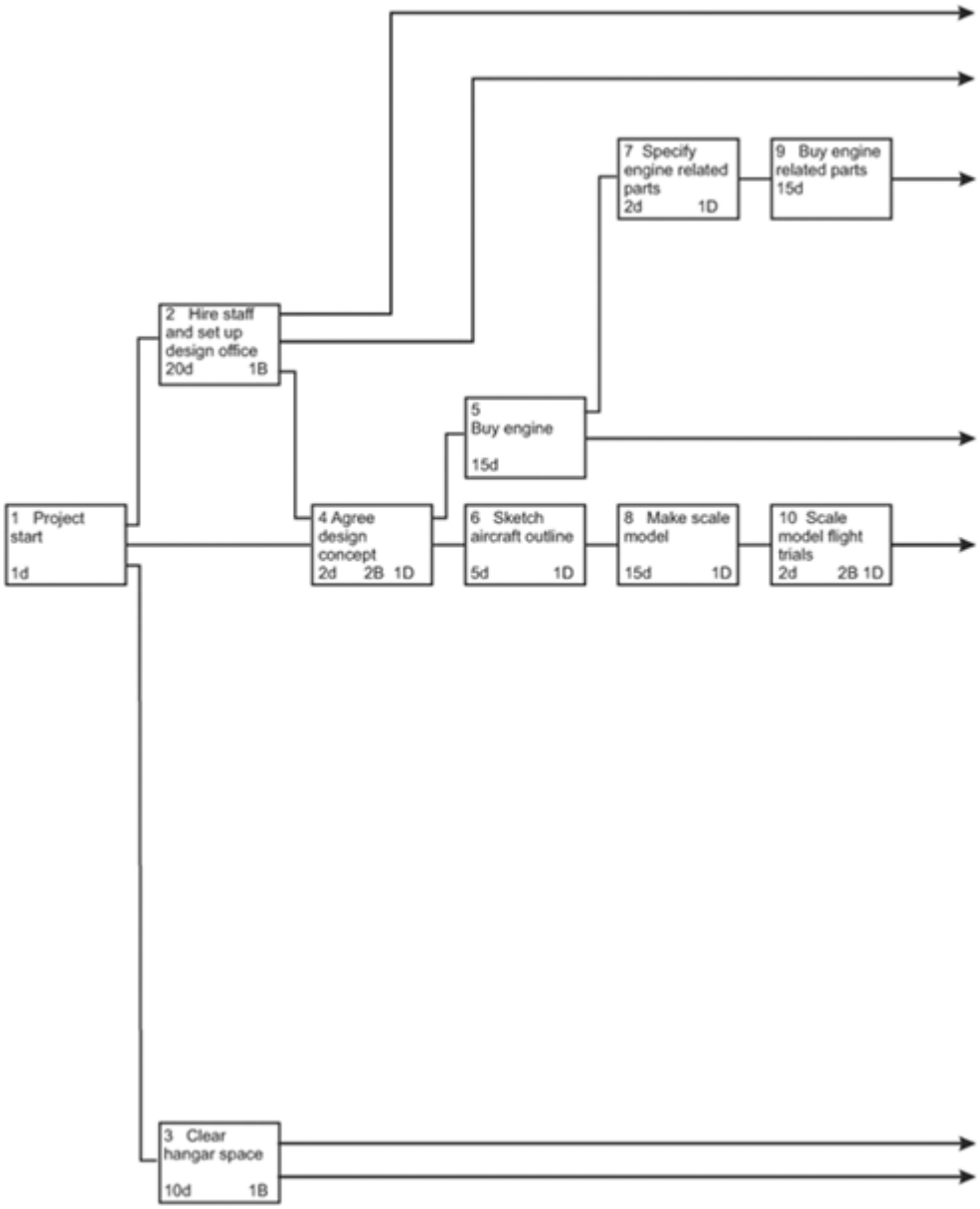
- Designer—The brothers will need to hire one aircraft design engineer for the duration of the project (with a possible contract extension to work on future projects). He or she will be coded D for designer in the project scheduling system. The designer will produce all the construction drawings, and will also be on hand during some other tasks and ground testing.
- Avionics engineer—The brothers will need to hire an avionics engineer who can help with specifying the avionics and navigation equipment and who will also be asked to design all the aircraft wiring and instrument panel. This person will be on hand to supervise and help with some of the wiring tasks carried out by an electrician temporarily taken from the car repair workshops. The avionics engineer will be coded A. The electrician will not be included in the resource scheduling but the avionics engineer will.
- Fitters—For their first project, the two brothers will assemble the plane themselves, using their automotive skills and tools. Each will be coded B (for brother) and the total availability will be 2B at any time. For some critical assembly tasks the brothers will require the designer to be on hand to ensure that everything is put together safely and as intended.

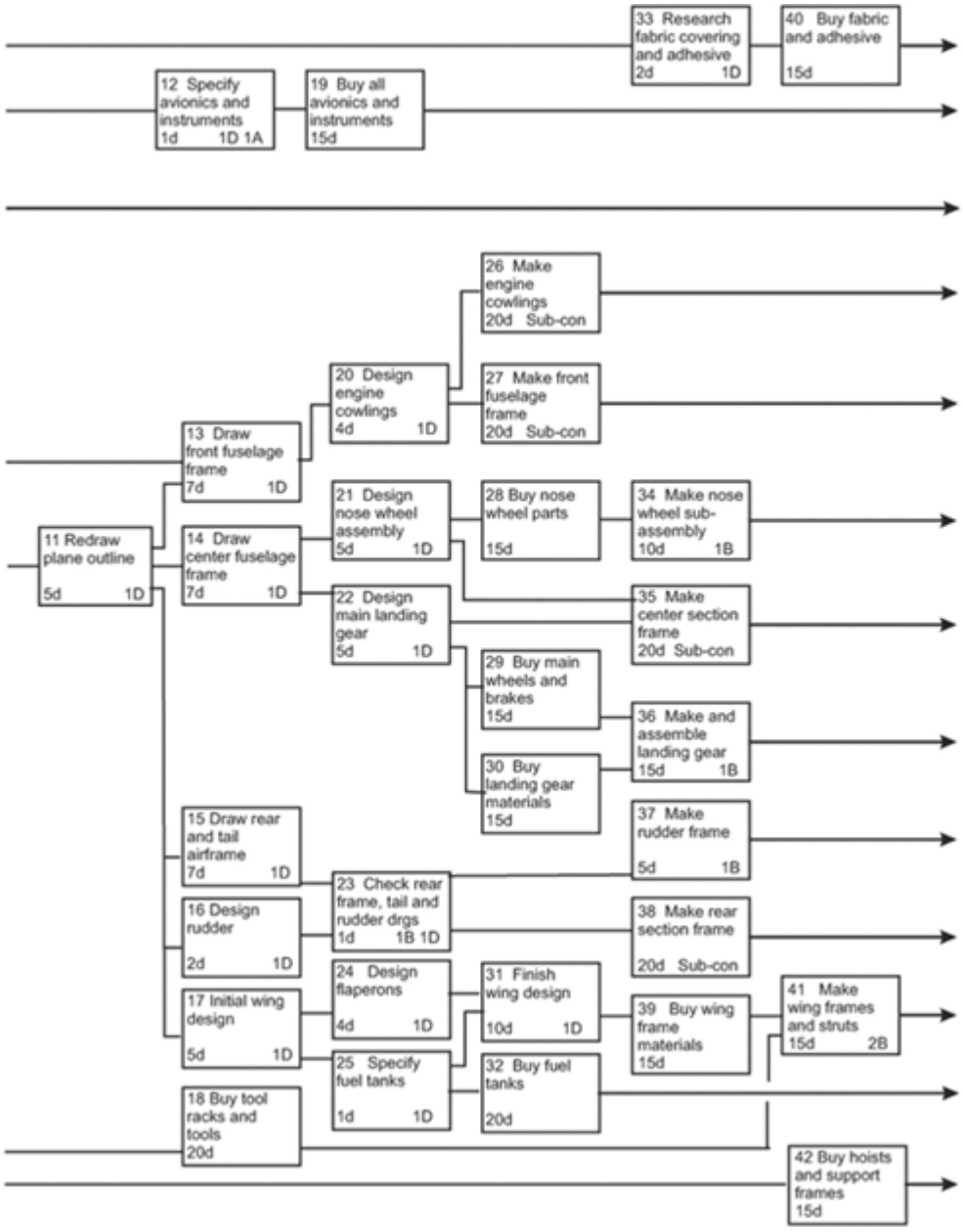
All other task resources will be provided by local sub-contractors, so they will not need to be scheduled. Thus this plane will be developed in a hands-on fashion, with the designers producing sketches from which manufacture and assembly will take place, and then the final drawings will emerge when all the trial and error processes have been finished.

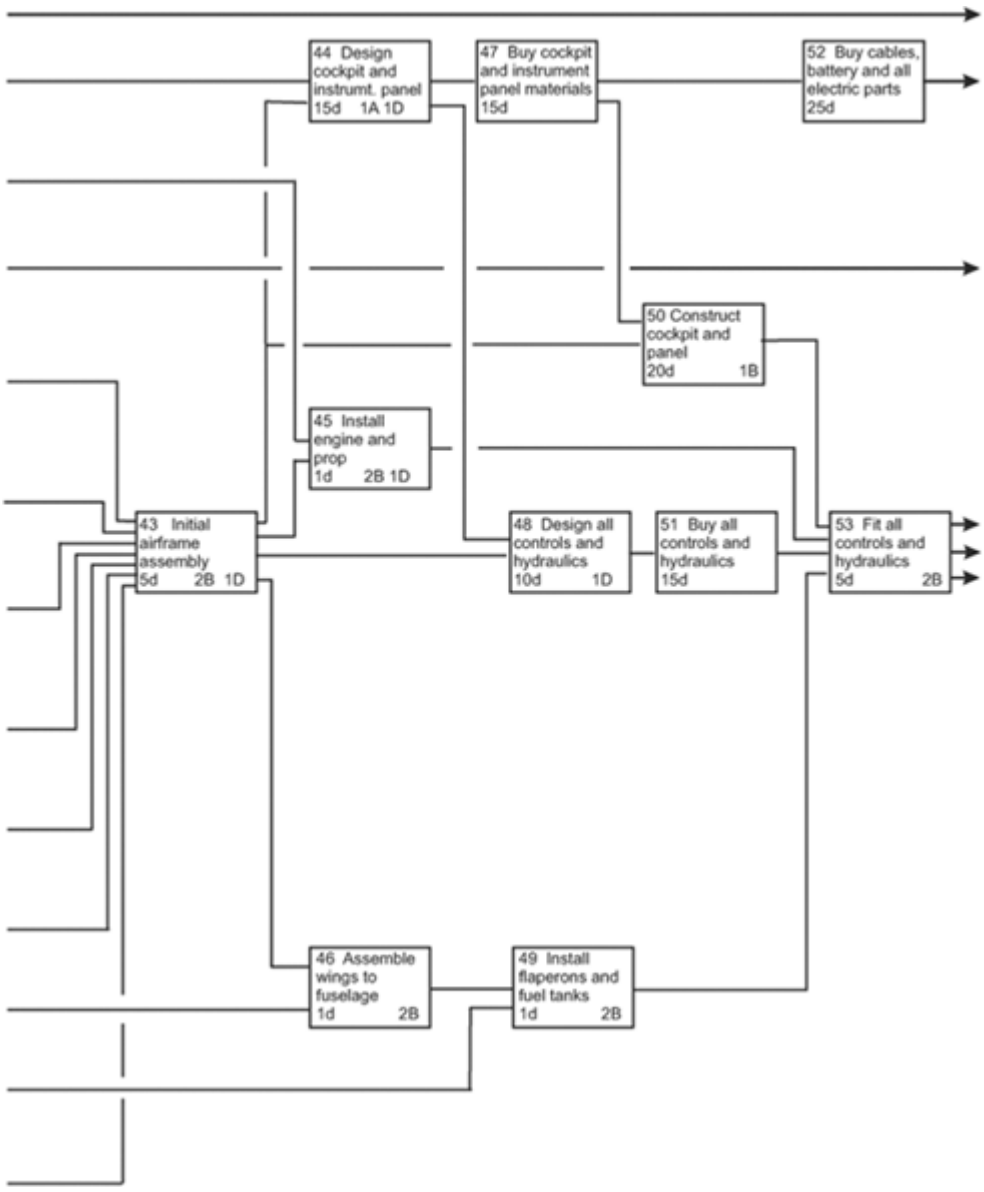
Critical Path Network Diagram

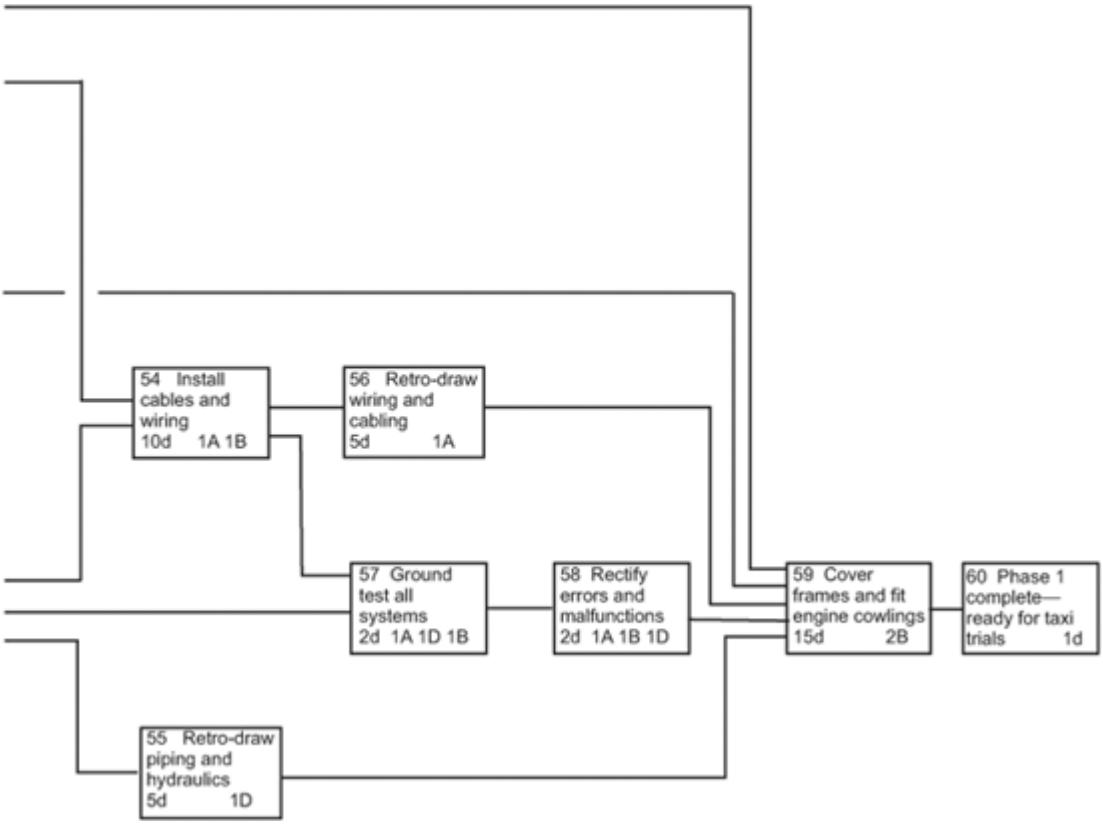
The brothers, recognizing that they have no project management experience, have called in a colleague to help them with the project management and she conducted a session with them that occupied all three for a full afternoon.

The resulting network diagram is shown in Figure 16.6. This incorporates all the significant intended manufacturing and design strategy.


1 Project start 1d
2 Hire staff and set up design office 20d 1B
3 Clear hangar space 10d 1B
4 Agree design concept 2d 2B 1D
5 Buy engine 15d
6 Sketch aircraft outline 5d 1D
7 Specify engine related parts 2d 1D
8 Make scale model 15d 1D
9 Buy engine related parts 15d
10 Scale model flight trials 2d 2B 1D


33 Research fabric covering and adhesive
2d 1D
40 Buy fabric and adhesive
15d
12 Specify avionics and instruments
1d 1D 1A
19 Buy all avionics and instruments
15d
26 Make engine cowlings
20d Sub-con
20 Design engine cowlings
4d 1D
27 Make front fuselage frame
20d Sub-con
13 Draw front fuselage frame
7d 1D
21 Design nose wheel assembly
5d 1D
28 Buy nose wheel parts
15d
34 Make nose wheel sub-assembly
10d 1B
11 Redraw plane outline
5d 1D
14 Draw center fuselage frame
7d 1D
22 Design main landing gear
5d 1D
35 Make center section frame
20d Sub-con
29 Buy main wheels and brakes
15d
36 Make and assemble landing gear
15d 1B
30 Buy landing gear materials
15d
37 Make rudder frame
5d 1B
15 Draw rear and tail airframe
7d 1D
23 Check rear frame, tail and rudder drgs
1d 1B 1D
38 Make rear section frame
20d Sub-con
16 Design rudder
2d 1D
24 Design flaperons
4d 1D
31 Finish wing design
10d 1D
39 Buy wing frame materials
15d
41 Make wing frames and struts
15d 2B
17 Initial wing design
5d 1D
25 Specify fuel tanks
1d 1D
32 Buy fuel tanks
20d
18 Buy tool racks and tools
20d
42 Buy hoists and support frames
15d


44 Design cockpit and instrumt. panel 15d 1A 1D
47 Buy cockpit and instrument panel materials 15d
52 Buy cables, battery and all electric parts 25d
50 Construct cockpit and panel 20d 1B
45 Install engine and prop 1d 2B 1D
43 Initial airframe assembly 5d 2B 1D
48 Design all controls and hydraulics 10d 1D
51 Buy all controls and hydraulics 15d
53 Fit all controls and hydraulics 5d 2B
46 Assemble wings to fuselage 1d 2B
49 Install flaperons and fuel tanks 1d 2B


54 Install cables and wiring 10d 1A 1B
56 Retro-draw wiring and cabling 5d 1A
57 Ground test all systems 2d 1A 1D 1B
58 Rectify errors and malfunctions 2d 1A 1B 1D
59 Cover frames and fit engine cowlings 15d 2B
60 Phase 1 complete—ready for taxi trials 1d
55 Retro-draw piping and hydraulics 5d 1D

Notes:

All durations are days.

Tasks pertaining to regulatory approvals are not shown.

A is the resource code for avionics engineer, who will also act as electrical engineer.
B is the resource code for either of the two Lox brothers, who will act as fitters.
D is the resource code for designer, an aviation engineer who will also assist generally.

All cabling, piping and control linkages will be assembled on the airframe and will be recorded on drawings retrospectively (tasks 53 and 58).

Sub-con is an abbreviation of sub-contractor and refers chiefly to stainless steel weldments that cannot be constructed by the Lox Brothers staff. These tasks do not need to be resource scheduled.

All buying will be done through the Lox brothers' automobile business, which has a buying office.

In this network 'buy' durations include everything from placing the order to receiving the goods.

Figure 16.6 Network diagram for Phase 1 of the Lox Brothers' first aircraft development project

The Schedule Results

We used Open Plan Professional to analyze this network and schedule the three resource categories. This software produces some excellent graphics that exploit the use of color intelligently. Clearly we could not reproduce all of these reports in these pages, but we have been able to illustrate the essential points by redrawing the relevant graphics in monochrome to a reduced scale. In spite of these limitations, the images shown here bear a close resemblance to the originals.

Open Plan Professional is not at first user friendly, and one is faced by a number of screens that appear complicated and difficult to understand. However, once the methods have been learned, entering data is very easy, and all the activity and resource data entry forms are very well designed. This is what we mean by software that has been developed with professional planners in mind. It originated with Welcom Software International, a Texas-based company. Like so many good products its development benefited from user group input and it is now a Deltek product <http://www.deltek.com>.

Initial time analysis It is always sensible to run simple time analysis before the resource schedules because the results, apart from their management interest, will help to highlight and eliminate errors in the data input. We specified a project start (and time-now) date of 5 March 2012. Open Plan uses the sensible date format 05Mar12 throughout its reports. Open Plan produces a log report in Notebook for time analysis and resource scheduling, and the time analysis version is particularly useful because it lists all start and finish dangles (there should only be one of each of these if the data input was correct).

Time-limited resource schedule When this project was run in time-limited resource scheduling mode, Open Plan reported several days when the stated availability limits of resources had to be exceeded if completion was to be maintained by 21Nov12. We have condensed this log report into two columns in Figure 16.7. The Lox Brothers would have needed to bring in one extra design engineer and one more avionics engineer to deal with these overloads and satisfy the earliest possible completion date.

Resource-limited schedule When the schedule was run again with the resource-limited rule imposed, the project completion date went out to 03Jan13. The scheduling log from Open Plan is shown in Figure 16.8.

Imposing the resource-limited constraint added about seven weeks to the scheduled project duration. We did not take the trouble to exclude any public holidays from the default calendar (perhaps we should have done) so taking time off for the Christmas and New Year breaks would have increased this delay in practice. However, the Lox brothers were sufficiently keen to work through holidays to clear delays. Many managers would consider that the additional seven weeks' duration would be worthwhile to avoid the expense of having to recruit and brief two additional engineers.

Figure 16.9 is a condensed version of the activity spreadsheet that Open Plan provided at the left-hand side of its Gantt chart view. Our illustration shows the results after resource-limited scheduling. A vital feature of this report is that it shows, in addition to the earliest start and finish times for each task taken from initial time analysis, the scheduled dates produced after resource allocation. These scheduled dates provide a work-to list for the entire project and are given here in the sensible and most practicable sort sequence of ascending scheduled start date.

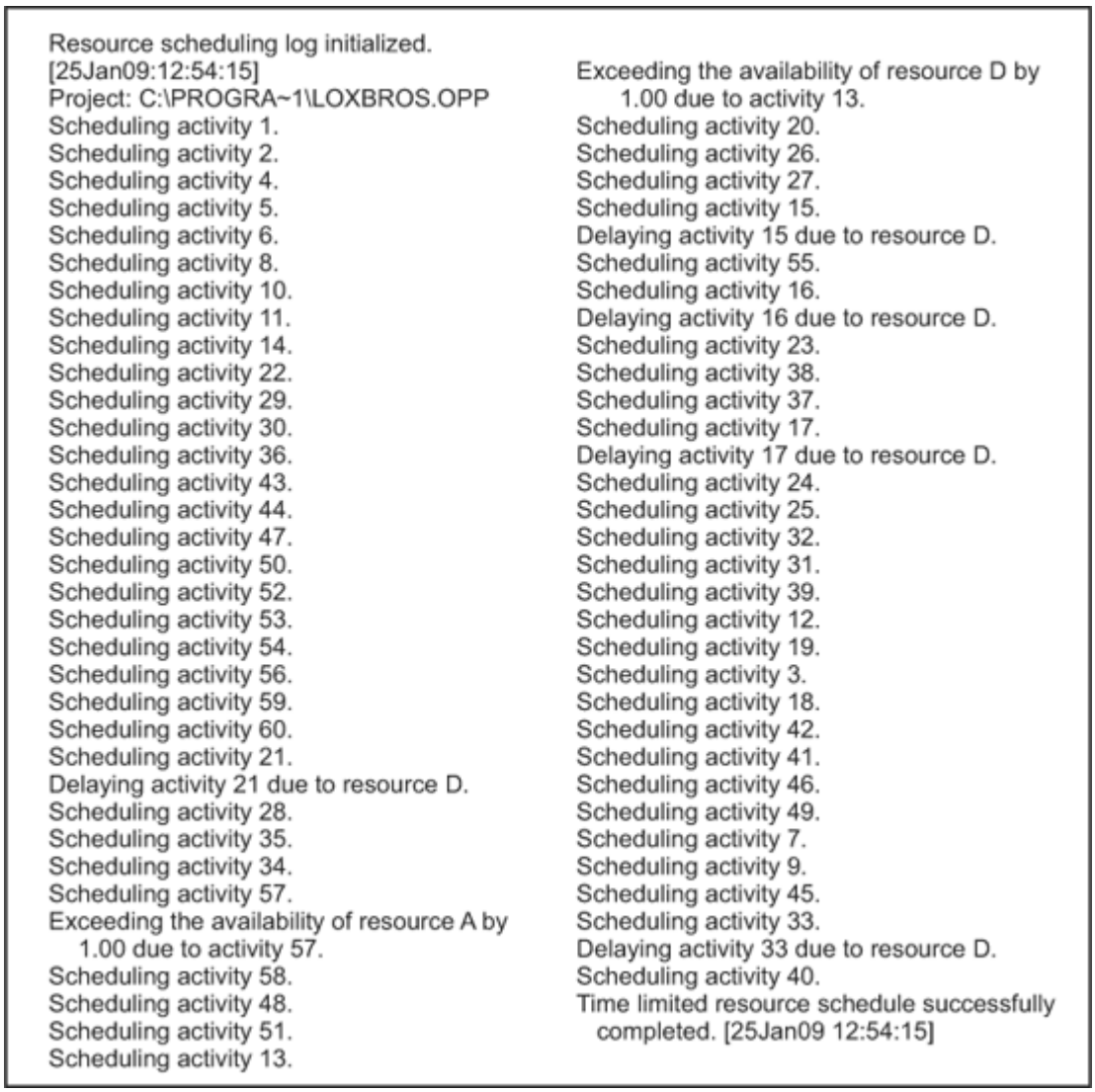


Figure 16.7 Log of Lox Brothers time-limited schedule processing by Open Plan

Resource schedule histogram We provide a flavor of the good graphics available from Open Plan in Figure 16.10, which is a small fragment redrawn from the time-limited resource histogram for the fitters (who are, you will remember, actually the two Lox brothers who own the new business).

In the original Open Plan report, blue bars represented the number of fitters needed day-by-day if all tasks were to be performed at their earliest possible dates without regard to resource availability. These are represented by the white bars in our illustration. Although no overload is shown in the fragment in Figure 16.10 significant overloads were predicted at earlier dates in the complete histogram. We could not show this earlier portion of the

histogram here owing to the amount of page space that would have been needed.

The gray bars in Figure 16.8 replace the mauve bars of the original Open Plan graphic, and these show the number of fitters that would be needed if all tasks were delayed to their latest permissible dates. What has happened here is that by delaying all tasks to their latest permissible dates as calculated from time analysis, the overloads previously predicted by scheduling all tasks at their earliest dates have been shifted so that they now occur later in the schedule, and are therefore included in the fragment that we are able to show here.

```
Resource scheduling log initialized. [25Jan09]
12:51:54]
Project: C:\PROGRA~1\LOXBROS.OPP
Scheduling activity 1.
Scheduling activity 2.
Scheduling activity 4.
Scheduling activity 5.
Scheduling activity 6.
Scheduling activity 8.
Scheduling activity 10.
Scheduling activity 11.
Scheduling activity 14.
Scheduling activity 22.
Scheduling activity 29.
Scheduling activity 30.
Scheduling activity 36.
Scheduling activity 21.
Delaying activity 21 due to resource D.
Scheduling activity 28.
Scheduling activity 35.
Scheduling activity 34.
Scheduling activity 13.
Delaying activity 13 due to resource D.
Scheduling activity 20.
Scheduling activity 26.
Scheduling activity 27.
Scheduling activity 15.
Delaying activity 15 due to resource D.
Scheduling activity 16.
Delaying activity 16 due to resource D.
Scheduling activity 23.
Delaying activity 23 due to resource B.
Scheduling activity 38.
Scheduling activity 37.
Scheduling activity 17.
Delaying activity 17 due to resource D.
Scheduling activity 24.
Delaying activity 24 due to resource D
Scheduling activity 25
Delaying activity 25 due to resource D
Scheduling activity 32.
Scheduling activity 31.
Scheduling activity 39.
Scheduling activity 12.
Delaying activity 12 due to resource D.
Scheduling activity 19.
Scheduling activity 3.
Scheduling activity 18.
Scheduling activity 42.
Scheduling activity 43.
Scheduling activity 44.
Scheduling activity 47.
Scheduling activity 52.
Scheduling activity 50.
Scheduling activity 48.
Scheduling activity 51.
Scheduling activity 41.
Scheduling activity 46.
Scheduling activity 49.
Scheduling activity 7.
Delaying activity 7 due to resource D.
Scheduling activity 9.
Scheduling activity 45.
Delaying activity 45 due to resource B.
Scheduling activity 53.
Scheduling activity 54.
Scheduling activity 56.
Scheduling activity 57.
Delaying activity 57 due to resource A.
Scheduling activity 58.
Scheduling activity 55.
Scheduling activity 33.
Delaying activity 33 due to resource D.
Scheduling activity 40.
Scheduling activity 59.
Scheduling activity 60.
Resource limited schedule
successfully completed
   [25Jan09 12:51:54]
```

Figure 16.8 Log of Lox Brothers resource-limited schedule processing by Open Plan



Project: LOXBROS
Time Now: 05Mar12
Start: 05Mar12
Finish: 03Jan13
Run: 24Jan09

Activity ID	Activity Desc.	Duration.	Total Float.	Early Start	Early FInish	Sched. Start	Sched. Finish
1	Project start	1d	0	05Mar12	05Mar12	05Mar12	05Mar12
3	Clear hangar space	10d	66d	06Mar12	19Mar12	06Mar12	19Mar12
2	Hire staff and set up office	20d	0	06Mar12	02Apr12	06Mar12	02Apr12
42	Buy hoists and support frames	15d	66d	20Mar12	09Apr12	20Mar12	09Apr12
18	Buy tools and racks	20d	98d	20Mar12	16Apr12	20Mar12	16Apr12
4	Agree design concept	2d	0	03Apr12	04Apr12	03Apr12	04Apr12
6	Sketch aircraft outline	5d	0	05Apr12	11Apr12	05Apr12	11Apr12
5	Buy engine	15d	23d	05Apr12	25Apr12	05Apr12	25Apr12
8	Make scale model	15d	0	12Apr12	02May12	12Apr12	02May12
10	Scale model flight trials	2d	0	03May12	04May12	03May12	04May12
11	Redraw plane outline	5d	0	07May12	11May12	07May12	11May12
14	Draw center fuselage frame	7d	0	14May12	22May12	14May12	22May12
22	Design main landing gear	5d	0	23May12	29May12	23May12	29May12
21	Design nose wheel assembly	5d	5d	23May12	29May12	30May12	05Jun12
30	Buy landing gear materials	15d	0	30May12	19Jun12	30May12	19Jun12
29	Buy main wheels and brakes	15d	0	30May12	19Jun12	30May12	19Jun12
13	Draw front fuselage frame	7d	11d	14May12	22May12	06Jun12	14Jun12
28	Buy nose wheel parts	15d	5d	30May12	19Jun12	06Jun12	26Jun12
35	Make center section frame	20d	10d	30May12	26Jun12	06Jun12	03Jul12
20	Design engine cowlings	4d	11d	23May12	28May12	15Jun12	20Jun12
36	Make and assemble landing gear	15d	0	20Jun12	10Jul12	20Jun12	10Jun12
15	Draw rear and tail airframe	7d	14d	14May12	22May12	21Jun12	29Jun12
26	Make engine cowlings	20d	91d	29May12	25Jun12	21Jun12	18Jul12
27	Make front fuselage frame	20d	11d	29May12	25Jun12	21Jun12	18Jul12
34	Make nose wheel sub assembly	10d	5d	20Jun12	03Jul12	27Jun12	10Jul12
16	Design rudder	2d	19d	14May12	15May12	02Jul12	03Jul12
17	Initial wing design	5d	45d	14May12	18May12	04Jul12	10Jul12
23	Check rear frame drawings	1d	14d	23May12	23May12	11Jul12	11Jul12
24	Design flaperons	4d	45d	21May12	24May12	12Jul12	17Jul12
37	Make rudder frame	5d	29d	24May12	30May12	12Jul12	18Jul12
38	Make rear section frame	20d	14d	24May12	20Jun12	12Jul12	08Aug12
25	Specify fuel tanks	1d	48d	21May12	21May12	18Jul12	18Jul12
31	Finish wing design	10d	45d	25May12	07Jun12	19Jul12	01Aug12
32	Buy fuel tanks	20d	70d	22May12	18Jun12	19Jul12	15Aug12
12	Specify avionics and instruments	1d	60d	03April12	03Apr12	02Aug12	02Aug12
39	Buy wing frame materials	15d	45d	08Jun12	28Jun12	02Aug12	22Aug12
7	Specify engine related parts	2d	91d	26Apr12	27Apr12	03Aug12	06Aug12
19	Buy avionics and instruments	15d	60d	04Apr12	24Apr13	03Aug12	23Aug12
33	Research fabric and adhesive	2d	134d	03Apr12	04Apr12	07Aug12	08Aug12
9	Buy engine related parts	15d	91d	30Apr12	18May12	07Aug12	27Aug12
43	Initial airframe assembly	5d	0	11Jul12	17Jul12	09Aug12	15Aug12
40	Buy fabric and adhesive	15d	134d	05Apr12	25Apr12	09Aug12	29Aug12
41	Make wing frame and struts	15d	45d	29Jun12	19Jul12	23Aug12	12Sep12
44	Design cockpit and instrument pa	15d	0	18Jul12	07Aug12	24Aug12	13Sep12
46	Assemble wings to fuselage	2d	45d	20Jul12	23Jul12	13Sep12	14Sep12
48	Design hydraulics	10	10d	08Aug12	21Aug12	14Sep12	27Sep12
47	Buy cockpit and instrument panel	15d	0	08Aug12	28Aug12	14Sep12	04Oct12
49	Install flaperons and fuel tanks	1d	45d	24Jul12	24Jul12	17Sep12	17Sep12
45	Install engine and prop	1d	49d	18Jul12	18Jul12	28Sep12	28Sep12
51	Buy controls and hydraulics	15d	10d	22Aug12	11Sep12	28Sep12	18Oct12
50	Construct cockpit and panel	20d	0	29Aug12	25Sep12	05Oct12	01Nov12
52	Buy cables, battery and electrics	25d	0	29Aug12	02Oct12	05Oct12	08Nov12
53	Fit controls and hydraulics	5d	0	26Sep12	02Oct12	02Nov12	08Nov12
55	Retro-draw piping and hydraulics	5d	15d	03Oct12	09Oct12	09Nov12	15Nov12
54	Install cables and wiring	10d	0	03Oct12	16Oct12	09Nov12	22Nov12
56	Retro-draw cables and wiring	10d	0	17Oct12	30Oct12	23Nov12	06Dec12
57	Ground test systems	2d	6d	17Oct12	18Oct12	07Dec12	10Dec12
58	Rectify errors and malfunctions	2d	6d	19Oct12	22Oct12	11Dec12	12Dec12
59	Cover frames and fit engine cowli	15d	0	31Oct12	20Nov12	13Dec12	02Jan13
60	Phase 1 complete, ready for taxi t	1d	0	21Nov12	21Nov12	03Jan13	03Jan13

Figure 16.9 Resource-limited work-to list for the Lox Brothers project (Open Plan Professional)

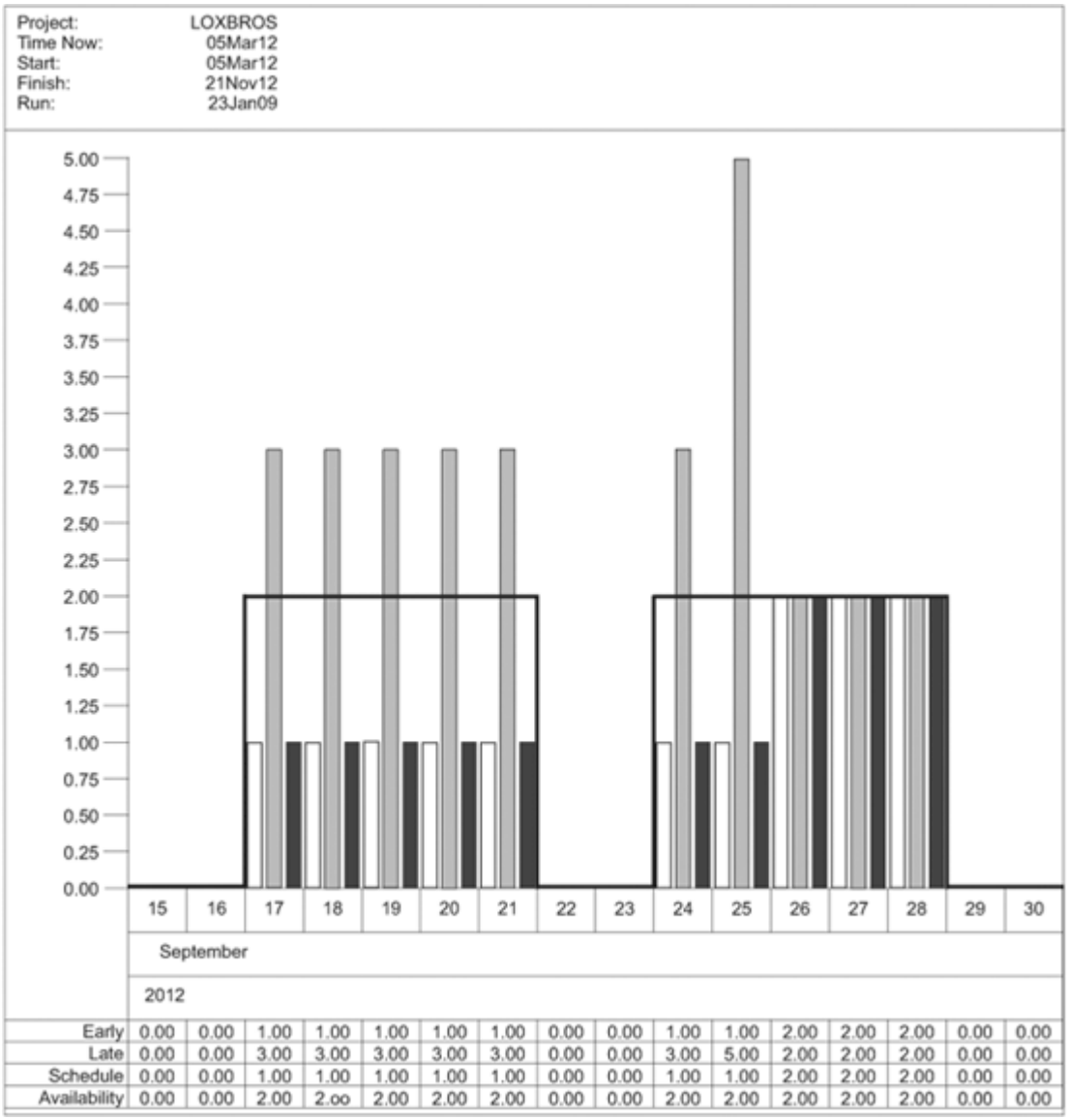


Figure 16.10 Fragment of a time-limited resource histogram for Lox Brothers fitters (Open Plan)

However, we are chiefly concerned as sensible project managers with the scheduled resource requirement after resource leveling, shown in green on the original Open Plan report and black in our version. In this fragment it is clear that the resource limit of two fitters (the two Lox brothers) does not need to be exceeded, and that was true throughout the whole period of this project schedule. Open Plan did delay the scheduled times of some tasks beyond their possible earliest times but within their available float to make this level result possible. Those delays were listed in the commentary in Figure 16.7.

17
Planning For Risk and Uncertainty in Aviation Projects

Everything we do from getting out of bed in the morning to returning there at night carries risk. Every journey carries some risk, whether it is by bicycle, car, train, ship, plane or even walking. It is not surprising that projects, which metaphorically (and sometimes literally) break new ground, attract many risks. Project risks can be predictable or completely unforeseeable. They might be caused by the physical elements or they could be political, economic, commercial, technical or operational in origin. Freak events have been known to disrupt important projects, such as the decision by a few family members of a rare protected species to establish their family home on ground that was just about to be trenched for an oil pipeline or the unexpected discovery of important archaeological remains under land destined to carry one of the main runways at a new airport.

The potential effects of risks range from trivial inconvenience to project disaster. Project risk management (and much of mainstream project management) is concerned with attempting to identify all the foreseeable risks, assessing the chance and severity of those risks, and then deciding what might be done to reduce their possible impact on the project or avoid them altogether.

In some industries risk management and its closely associated discipline of reliability engineering have to be taken particularly seriously because of the potential impact of project failure on public safety or the environment. Examples are projects for defense, nuclear power plants, petro-chemical plants and all projects involving the transport of people in air or other modes of transport. High in this list of risk-sensitive projects are all those connected with aerospace and air transport, where a risk event might be anything from missing a flight connection to a catastrophic collision between two fully laden passenger aircraft over a densely populated city.

INTRODUCTION TO PROJECT RISK MANAGEMENT

Risks affecting project design and progress can occur at any stage in a project. Some are associated with particular tasks and others originate from outside the project and can manifest themselves without warning. Generally speaking, a risk event that occurs late in a project can be more costly in terms of time and money than a similar event nearer the start of the project. That is because as time passes there will be a greater value of work in progress and higher sunk costs at risk of loss or damage.

Some projects, because they are small or similar to projects that the contractor has undertaken in the past, might not need special attention to risk management other than considering some insurance issues. However, for any project that breaks new ground or is complex and large, a risk management strategy must be developed, first to identify as many potential risks as possible and then to decide how to deal with them.

For very large projects it might be necessary to appoint a risk manager, who can devote all or most of his or her time to ensuring that a comprehensive risk strategy is put in place and then reviewed from time to time throughout the project to ensure that it remains valid. If a project support office exists, that is a logical place for the risk management function to reside.

Project risk management is a complex subject. Even the classification of risks is not straightforward and can be approached in different ways. There are several techniques for assessing and dealing with project risks, some of which are shared with other management disciplines (particularly with quality management and reliability engineering). This chapter will outline a few of the methods commonly used in project risk management, with a brief detour into the closely related subject of reliability engineering.

UNCERTAINTY ABOUT TIME AND COST ESTIMATES

In this section we deal with uncertainty in the sense that we might not have complete confidence in the data on which we have based our project planning. In particular, how confident can we be that our time and cost estimates will prove to be accurate when the project is executed?

In Chapter 14 we used a case example to demonstrate how applying three time estimates for each task using PERT might be used to help us to arrive at

more reliable time estimates. Another method for helping to remove fears about uncertainty is Monte Carlo analysis. We outlined that method in Chapter 6 in the context of dealing with uncertainty about financial data in the business plan. Now we include a case example to show how Monte Carlo analysis can predict the probability of a project running early or late.

Monte Carlo analysis bears some resemblance to PERT, in the sense that both methods seek to deal with uncertainty about how time estimates will match actual performance and both methods start out by requiring three time estimates (optimistic, most likely and pessimistic) for each task. However, in PERT the three estimates for each task are substituted in a formula that modifies the original estimates to arrive at the expected time for each task. Monte Carlo analysis takes a more fundamental approach and substitutes the optimistic, most likely and pessimistic estimates at random across the network diagram in a large number of time analysis iterations. We can demonstrate this approach here, using the Lox Brothers project from the previous chapter as a case example.

Case Example: Monte Carlo Analysis of the Schedule for the Lox Brothers Project

The project This project was described in the case example at the end of Chapter 16. There we used Open Plan to carry out time analysis and resource scheduling and discovered that the earliest possible completion time for this project would be 21 November 2012, provided that it started on 5 March 2012 and we allowed a few resource overloads.

Applying the three time estimates We decided to apply three time estimates only to those tasks that were critical or had total float of 21 days or less. To allocate three time estimates to tasks with large amounts of float would be a waste of time because those tasks could not possibly affect project completion time. Thus just over half of this project's 60 tasks required three estimates, and they are listed in Figure 17.1

ID	Description	Original duration estimate	Optimistic duration estimate	Original duration estimate
2	Hire staff and set up office	20d	15d	30d
4	Agree design concept	2d	1d	3d
5	Buy engine	15d	12d	25d
6	Sketch aircraft outline	5d	3d	6d
8	Make scale model	15d	10d	18d
10	Scale model flight trials	2d	2d	10d
11	Redraw plane outline	5d	4d	6d
13	Draw front fuselage frame	7d	5d	8d
14	Draw center fuselage frame	7d	5d	8d
15	Draw rear fuselage and tail frame	7d	6d	10d
16	Design rudder	2d	1d	4d
20	Design engine cowlings	4d	2d	5d
21	Design nose wheel assembly	5d	3d	6d
22	Design main landing gear	5d	3d	6d
23	Check rear frame drawings	1d	1d	2d
27	Make front fuselage frame	20d	18d	30d
28	Buy nose wheel parts	15d	10d	20d
29	Buy main wheels and brakes	15d	10d	18d
30	Buy landing gear materials	15d	12d	20d
34	Make nose wheel sub assembly	10d	5d	12d
35	Make center section frame	20d	18d	25d
36	Make and assemble landing gear	15d	10d	18d
38	Make rear section frame	20d	18d	25d
43	Initial airframe assembly	5d	3d	6d
44	Design cockpit and instrument panel	15d	10d	20d
47	Buy cockpit and instrument panel material	15d	12d	20d
48	Design hydraulics	10d	5d	12d
50	Construct cockpit and instrument panel	20d	15d	25d
51	Buy controls and hydraulics	15d	10d	20d
52	Buy battery, cables and electrics	25d	15d	30d
53	Fit controls and hydraulics	5d	4d	10d
54	Install cables and wiring	10d	8d	12d
55	Retro-draw piping and wiring	5d	3d	6d
56	Retro-draw cables and wiring	10d	4d	12d
57	Ground test systems	2d	1d	3d
58	Rectify errors and malfunctions	2d	1d	10d
59	Cover frames and fit engine cowlings	15d	12d	20d

Figure 17.1 Tasks selected for three duration estimates from the Lox Brothers project

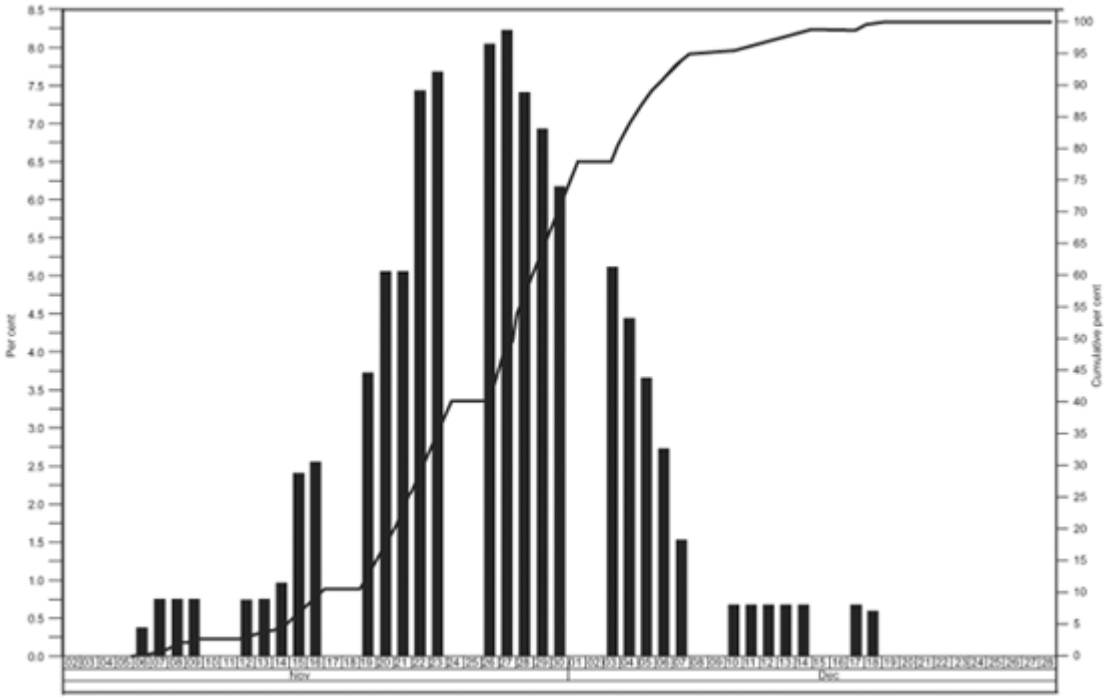


Figure 17.2 Monte Carlo analysis of the Lox Brothers' project after 1000 iterations using Open Plan software

The result Figure 17.2 shows the report produced by Open Plan after we commanded the program to perform 1000 Monte Carlo iterations, which it did in about three seconds. This software uses a random number generator to pick which of the three time estimates to apply for every task in each time analysis calculation. The height of each bar in the resulting histogram is directly proportional to the number of times (frequency in statistical terms) that a particular completion date was predicted. The Y axis at the left-hand side of the diagram is scaled to show the percentage of the 1000 iterations that produced each time prediction.

The cumulative graph line which extends from left to right through the diagram is scaled vertically to show the probability of the project being finished by each date. This result is expressed as a percentage, and the scale on the right-hand Y axis applies.

Thus it is seen that the earliest possible completion date for this project is 6 November 2012, and the most likely or expected completion date is 26 November 2012. Barring unforeseen risks or accidents this project is 100 per cent certain to finish by 18 December 2012.

IDENTIFYING THE POSSIBLE RISKS

Projects can incur risks from the 'accident waiting to happen' variety to the most unexpected and bizarre. Risks can materialize during project design and execution or after the project is finished and has been handed over to the customer.

Management change and IT projects seem to be particularly prone to risk of failure, with huge losses of money, delay in completion or malfunctions. Projects in the aviation industry appear to have been vulnerable to failure through IT failure. The Airbus 380 project was such a case during its development, where design faults in the original wiring harnesses have been attributed to collaborating manufacturers using different versions of CAD software. There have been many reported instances of problems with both on-board and ground computer systems. For example, chaos can result if a flight reservation and ticketing system malfunctions. Air traffic control systems appear to have been vulnerable, with malfunctions causing widespread grounding of flights and with obvious potential to cause flight hazards. The frequently updated website <http://www.lessons-from-history.com> has a section labeled 'project success or failure' which has a rich fund of project failure stories, many of which are aviation based.

Checklists

We make no excuse for stressing the value of checklists at several places throughout this book, because each checklist is built on a fund of experience and can be a vital factor in preventing errors of omission in current and future projects and in operations.

In the project risk management context, checklists are important for suggesting or identifying project risks. Studying the history of similar projects from the past can highlight possible problems and help the project manager to learn from the experiences (and mistakes) of others. As experience is gained on each new project, the project manager and others will be able to improve and enrich the existing checklists from their new experiences. Individual experience can never itself be a substitute for a checklist that enshrines the experiences of many others: it should be regarded instead as an enabler for further checklist improvement and enrichment.

In this book we are discussing principally the project management aspects of checklists, but clearly checklists (along with instruction and operating manuals, training and emergency exercises) play a vital part in maintaining the safety of ground and air operations.

Figure 17.3 is an example of a form that, although intended as an engineering project authorization document, is effectively also a checklist because it demands answers to a structured list of questions. This is an example of procedure that is designed to reduce the risk of design errors and improve engineering reliability. This versatile form can be used in conjunction with a new engineering design, as part of the risk management process, as an authorization document for a small engineering project or during the consideration of a proposed project engineering modification or change (changes are dealt with in Chapter 23).

Brainstorming

Brainstorming is an effective technique for identifying possible risks. The method relies particularly on the assertion that two heads are better than one, and its effectiveness depends on allowing all those who take part complete freedom of thought and imagination with no preconceived agenda. A brainstorming meeting of key staff is a particularly productive method for identifying all the possible project risks along with many of the improbable ones.



Verulam Airways
ENGINEERING PROJECT (EP)

Document ID:	Date issued:	Revision number:
Title:		
Document type:	Originator:	
Date received:	Assigned to:	

OPTIONS

Attach to new EP:	EP title:	
Attach to existing EP:		
Detach from existing EP:		(employee number)
Fleet number:		
Units/aircraft affected (cross reference field, airframe, power plant, component, group year):		
Related documents (cross reference field, MD/AA/EPs):		
Miscellaneous references:		
Project description:		
Project scope:		

Engineer's name:	ID number:	Phone extension:	email address:

STATUS → Open: ☐ In review: ☐ Closed: ☐ EP number:

ENGINEERING INVESTIGATION

Reliability:		Planning:	
EP Required by:		WARRANTY: → Yes: ☐	No: ☐
Response:			
Respondent's name:	ID number:	Phone extension:	email address:

Figure 17.3 A versatile initial checklist/authorization document for small aviation engineering projects

Much depends on how the brainstorming session is conducted. The leader or chairperson should encourage an atmosphere of 'anything goes'. Participants should be asked to think of all the possible things that might go wrong with the project, or as a result of the project. Participants must feel free to propose even the most bizarre risks without fear of ridicule. All suggestions, without exception, should initially be written on whiteboards or flip charts.

When all creative imagination has been exhausted, the resulting lists can be examined critically, first to exclude the absolutely impossible entries and then to create an initial risk identification register.

RISK APPRAISAL AND ANALYSIS

Once identified and listed, risks can be ranked according to the probability of their occurrence and the severity of the impact if they should occur. This process will eliminate the most improbable risks arising from brainstorming, but it should bring to the fore those risk events that are most likely to happen and which would have the greatest impact on the project or on subsequent ground or flight operations. For this analysis it is necessary to consider the possible causes and effects of every risk.

Risk analysis can be either qualitative or quantitative. Qualitative risk analysis involves considering each risk in a purely descriptive way, to imagine various characteristics of the risk and the effects that these could have on the project or subsequent operations. Quantitative risk analysis goes at least one stage further than qualitative analysis by attempting to quantify the outcome of a risk event or to attach a numerical score to the risk that ranks it according to its perceived claim for preventive or mitigating action.

QUALITATIVE CAUSE AND EFFECT ANALYSIS

Fishbone Diagrams

Ishikawa fishbone diagrams are methods commonly used by reliability and safety engineers to analyze or predict faults in design and construction. Project risk managers can adapt Ishikawa fishbone diagrams to examine risk cause and effect relationships. Figure 17.4, for instance, shows how an Ishikawa fishbone diagram might be compiled to analyze the numerous

reasons why an engine might lose power or stop. Many items in this example could be expanded into greater detail, leading to quite a complex diagram, with many branches and sub-branches to the 'fish skeleton'.

Fishbone diagrams can also be used in similar fashion to examine and analyze failures or poor performance in project organizations or communications. The fishbone process generally starts by thinking about the effect, and then looking back for the possible causes. However, project risk management is more often conducted from the opposite viewpoint, which means first listing all the possible causes (risks) first and then assessing their probable effects.

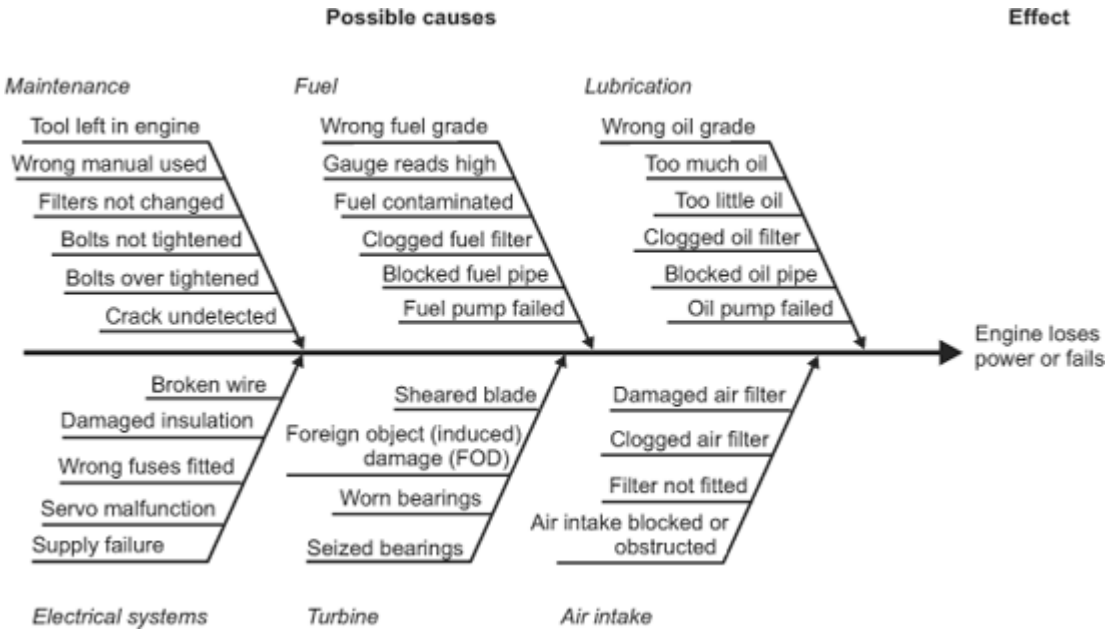


Figure 17.4 A simplified Ishikawa fishbone cause and effect diagram

Fault-tree Analysis (FTA) in Engineering Design

Most of the analytical methods used in project risk management have their parallels in engineering design. The Ishikawa fishbone method is one example of a fault-tree method but we must make mention here of another fault-tree method that has important applications in reliability engineering. This process examines the possibility of component failures in all kinds of engineering systems, with a view to improving safety and reliability. For example one application is to ensure that if a component fails the system shuts down in failsafe mode. The account that we give here is taken from

Newton (1994) and, because it applies more to engineering design than to project management, we need give only a brief introduction to the method, which in practice can be complex and take up many hours of investigation.

Elements and symbols used in fault-tree analysis (FTA) Symbols are used to assist in fault-tree analysis (FTA) notation, so that logical thoughts are more easily expressed and followed in flow diagrams. The methods and conventions benefit from work done at Bell Laboratories and at Boeing some years ago. Figure 17.5 shows symbols that are commonly used. These divide into two categories, events and gates.

FTA events FTA events have nothing to do with events more familiar to project managers as elements in critical path network diagrams. Instead they represent functions or faults in electrical, hydraulic and other systems.

- *Fault events* are complex failure events whose causes can be decomposed through logic gates (explained below) into a combination of simpler events. A particularly important fault event is the 'top event', which represents the failed system state that is being investigated or proposed.
- *Basic events* are failure events that cannot be further decomposed.
- *Undeveloped events* are events that would be capable of further decomposition if we had so decided. We might choose not to break them down further because the tree would not be affected by the lower failure levels, or simply because we are at an intermediate stage in producing the tree and further breakdown will take place later (in which case we use the double diamond symbol shown in Figure 17.5). In truth, all events are undeveloped because we could theoretically continue decomposing events down to the molecular level. One important FTA skill is knowing where to stop the breakdown process.

There are other events and symbols used in FTA but those shown in Figure 17.5 cover most cases.

Gates The two most widely used gates in FTA are the OR gate and the AND gate. These are, of course, familiar in the IT context although here we are concentrating on fault output results.

For an OR gate, the output fault event will occur if any one (or more) of the input events occurs.

For an AND gate, the output fault event will occur only if all the input events occur.

Transfers Although we show only a very simple example here, in practice fault trees can extend over several pages, and it also happens that sections of a tree will repeat in other parts of the tree. The transfer gate symbols shown in Figure 17.5 are used to denote the links between the various parts of the tree.

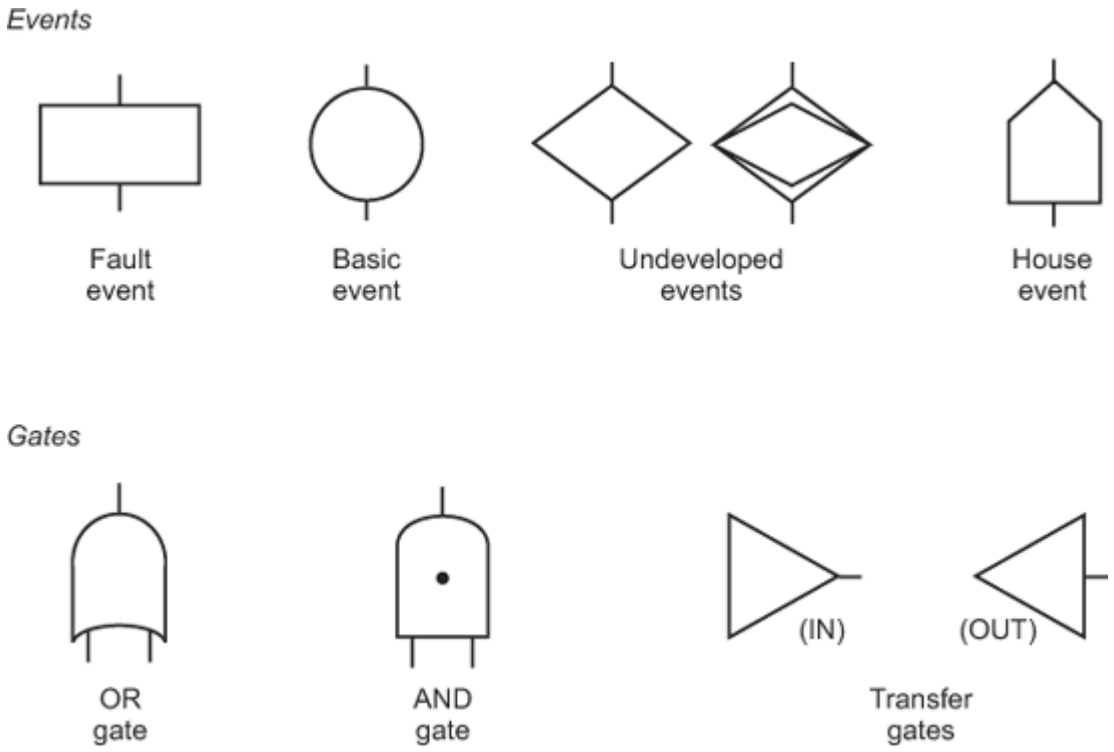


Figure 17.5 FTA symbols

A simple FTA case example Figure 17.6 shows fault trees developed to depict various failure modes in the control circuit for an electric motor. The system schematic is shown at Figure 17.6(a). It is seen that we have a motor connected to a dc electrical supply that can be interrupted by one or both switches, SW1 and SW2 which are connected in series. We are can define several top events for this system, and we shall examine those which have the greatest possibility of occurrence.

One top event possibility is that the motor fails to stop when one of the switches is turned to the off position. We could then throw the second switch to off, but if the motor still fails to stop the first reaction is that this can only be caused by both switches failing to open. The fault tree depicting this condition comprises these two basic events linked through an AND gate, as shown in Figure 17.6(b).

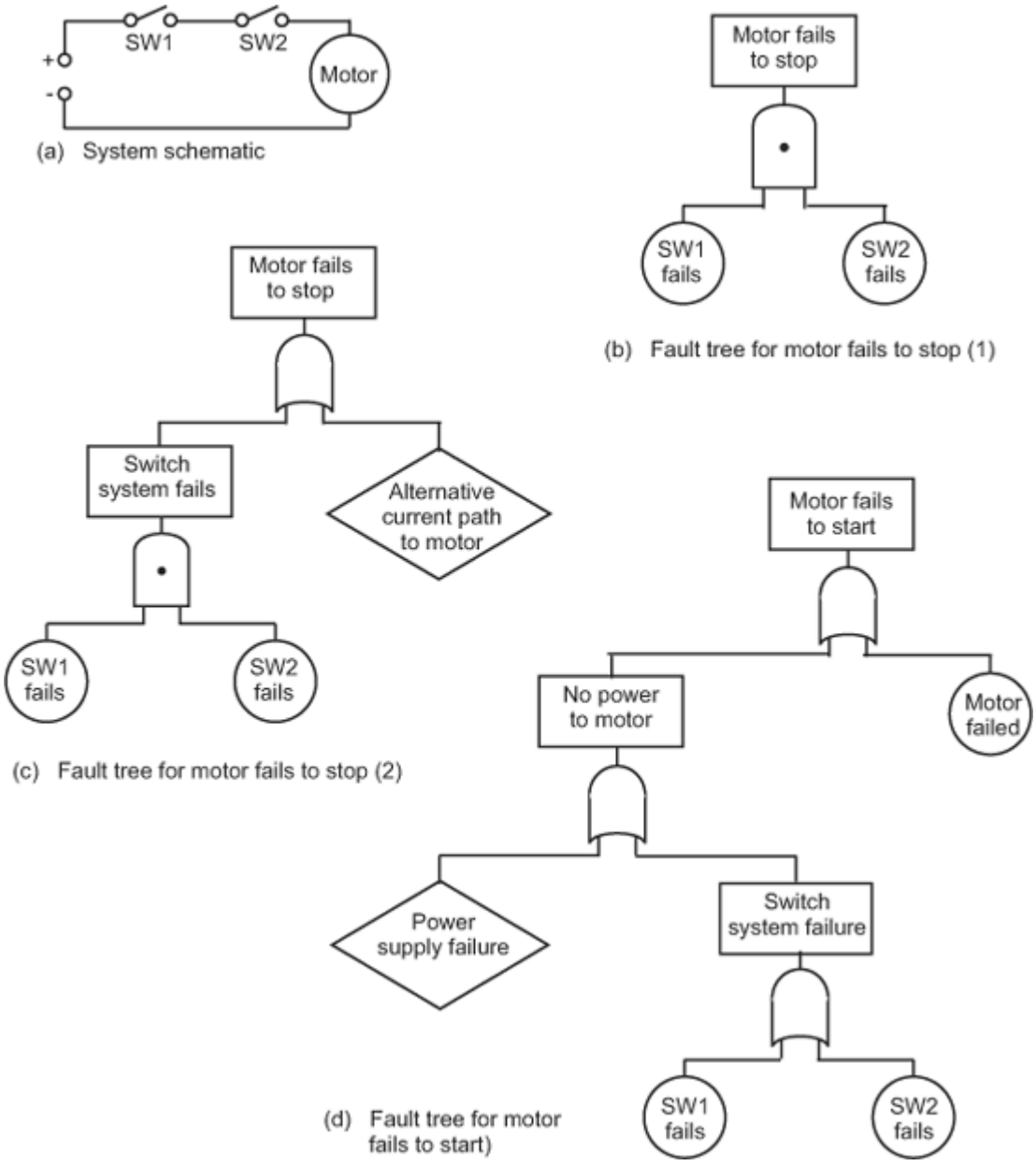


Figure 17.6 Fault trees for a motor control system

Further consideration might suggest other failure possibilities. For example, another current path might be present that does not pass through the two switches. This will alter the tree to the picture shown in Figure 17(c). Although the new event (the diamond) is shown undeveloped, there are all sorts of possibilities. For example a spanner could have been dropped into the equipment, shorting across the switches. This illustrates one of the complexities of FTA, in that it is limited only by the human imagination.

Another top event for this motor circuit would be that the motor fails to start as expected and required when both switches are closed. This condition is depicted at Figure 17(d). The simple explanations here could be a failure of one of the switches or a power supply failure. Clearly we could have developed the power supply failure event to examine all the possible causes.

Failure Mode and Effect Analysis (FMEA)

Failure mode and effect analysis (FMEA) is another example of a method that has been imported into project risk management from reliability and quality engineering, This method is particularly helpful to aviation project managers because it starts by considering possible risk events (failure modes) and then attempts to predict all their possible effects.

Figure 17.7 shows a simple FMEA chart, which represents only a tiny portion of a total FMEA chart for a municipal airport construction project. A final column allows space for pre-emptive actions to be recommended that might mitigate or prevent damage from the risk. Only three items are shown in Figure 17.5 but there might be hundreds of items in a large, complex project. Another column is sometimes added to show when in the project life cycle the risk is most likely to occur.

FMEA charts are a qualitative process because, although the characteristics of each risk are considered, there is no attempt to give each risk a priority ranking number or to quantify the effects if the risk should occur.

	Item	Failure mode	Cause of failure	Effect	Recommended pre-emptive action
1	Pilot's automobile	Engine refuses to start	Poor maintenance	Pilot marooned at private hunting lodge with no other means of transport. Unable to get to airstrip at project site.	Ensure good vehicle maintenance. Either keep back-up car at hunting lodge or don't go there.
2	New maintenance hangar	Floor over basement collapses during first aircraft engine exchange.	Errors in floor loading calculations when hangar was built	Personal injuries Damage to engines Damage to aircraft Schedules disrupted	Triple check vital structural calculations
3		Floor over basement collapses during first aircraft engine exchange	Floor slabs incorrectly poured	Personal injuries Damage to engines Damage to aircraft Schedules disrupted	Ensure operatives get good training and instruction. Employ competent site engineering manager.

Figure 17.7 Tiny part of a FMEA matrix for a new municipal airport

Risk Classification Matrices

Figure 17.8 shows a risk classification matrix chart. Note that this matrix comprises nine sections. Although this is a simple classification method, an even simpler four-section matrix is often used, containing the following quadrants:

- high chance—high impact;
- high chance—low impact;
- low chance—high impact;
- low chance—low impact.

As with FMEA, this again is a qualitative method, in which no attempt is made to evaluate any risk numerically. Each risk item is considered for its likelihood of occurrence (chance) and for the relative scale of the impact on the project should it occur.

Suppose, for instance, that a project is being planned to move a large airline company headquarters from a central city location to a purpose-built office building that is close to London Heathrow airport. The following are a few of the many risk events that might be visualized and assessed:

- Some office equipment could be damaged or stolen in transit. The risk of that happening might be high, but the impact could be considered medium because most equipment is easily replaceable.
- Some key staff might decide not to relocate with the company. That could be thought to have a medium chance, and the effect would have a medium impact on the company's performance when starting up in the new location.
- The collapse of the new premises just before occupation date through an earthquake in that part of the UK would be very low chance, but the impact would unquestionably be devastatingly high.
- The chance of moving day being made thoroughly miserable for all concerned through rain would be high, but with low practical impact.

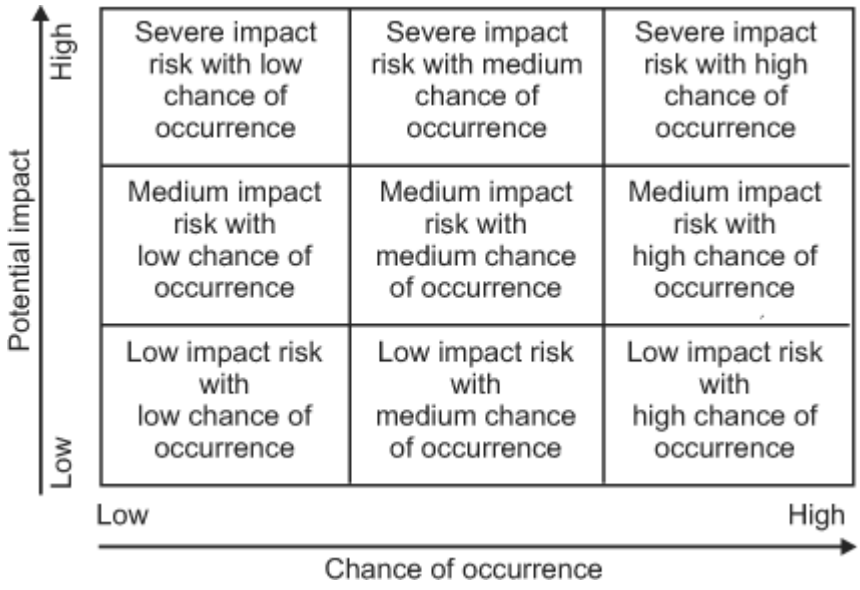

Potential impact
High
Low
Severe impact risk with low chance of occurrence
Severe impact risk with medium chance of occurrence
Severe impact risk with high chance of occurrence
Medium impact risk with low chance of occurrence
Medium impact risk with medium chance of occurrence
Medium impact risk with high chance of occurrence
Low impact risk with low chance of occurrence
Low impact risk with medium chance of occurrence
Low impact risk with high chance of occurrence
Low
High
Chance of occurrence

Figure 17.8 A matrix for qualitative risk classification

Figure 17.9 is a simple qualitative risk assessment matrix showing how the principles illustrated in Figure 17.4 might be applied in practice. This exercise is not complete, because as yet no thought has been given about what to do if any risk event should occur.

QUANTITATIVE ANALYSIS

Quantitative analysis methods attempt to assign numerical values to risks and their possible effects. They often examine the probable impact on project

time and costs. Alternatively, the evaluation process can produce a ranking number for every identified risk. Ranking numbers denote the priority that a risk should claim for management attention and expenditure on preventative measures.

Although all quantitative methods produce ‘actual’ numbers they can give a false sense of precision. We should remember that the results are based on estimates, assumptions and human judgment. Those contributing assessments might be fundamentally flawed, mistaken or simply too difficult for any person to make with any degree of certainty.

Failure Mode Effect Criticality Analysis (FMECA)

The qualitative FMEA method illustrated in Figure 17.7 can be adapted and extended to attempt risk quantification. The method then becomes failure mode effect and criticality analysis (FMECA). Figure 17.10 shows one version. In this example three assessment columns are provided, in each of which the risk analyst is expected to enter a number expressing the degree of significance. Every item is ranked on a scale of one to five (others use one to three or one to ten), with the highest numbers indicating the greatest degree of significance. The entries might be those of the risk analyst or, preferably, the collective opinions of a risk committee or brainstorming group. In some procedures the column headed ‘Detection difficulty’ is replaced by one headed ‘Prediction difficulty’.

Risk event	*Chance of happening*	*Potential severity*	*Difficulty of detection*	*Comment*
Action by environmentalists	High	High	Low	We shall be building in a nature reserve.
Strikes or other industrial action	Low	High	Low	Loyal workforce with no previous problems.
Project manager struck by lightning	Low	High	Low	But she is a keen golfer.
Hairline cracks in structural steel	Low	High	High	Suppliers have high quality reputation.
Software bugs	Medium	High	High	Process safety depends on computer controls.
Exchange rate changes	Medium	Medium	Low	Not difficult to detect but impossible to predict.
Materials shortages	Medium	Medium	Low	

Figure 17.9 A qualitative risk assessment matrix

Item two in Figure 17.10 for example, considers the possibility and potential seriousness of a structural failure in a new hangar. This is for a building created as part of an airport project, and the collapse in question might happen during heavy maintenance operations, such as the exchange of a large aircraft engine. If the floor has been incorrectly designed, and has pits or a basement below, it might not be sufficiently strong to carry the weight of two engines and the associated lifting rigs. The assessor clearly thinks this is unlikely to happen because she has ranked chance at the bottom end of the one to five scale. There is no doubt, however, that if this event did occur it would be extremely serious, so the severity has been marked as five.

Detection difficulty means the expected difficulty of noticing the cause of this risk (design error in this case) in time to prevent the risk event. Here there is a considerable element of judgment, but the assessor thinks that although the chance of a design error is very low, the difficulty of spotting a mistake if it did occur would be higher (three on the scale of one to five).

The product of these three parameters, $1 \times 5 \times 3$ gives a total ranking number of 15. Theoretically, when this calculation has been performed on

every item in the list, the list can be sorted in descending sequence of these ranking numbers, so that risks with the highest priority for management attention come at the top of the list.

Some assessors use weighted parameters. For example, it might be considered that the severity of the risk should play a higher part in deciding ranking priority. So the severity column could be marked on a higher scale, say from one to ten. Item two in Figure 17.5 might then be marked nine on this extended scale, which would increase the ranking factor for this item from 15 to 27.

Although not usual practice, a case might be argued for allowing zero scores in the 'Chance' and 'Severity' columns. That would, of course, result in a total ranking factor of zero. That would be one way, but not the most direct way, in which to dispose of some of the more outlandish risk events identified during an 'anything goes' brainstorming session.

Item		Failure mode	Cause of failure	Effect	Chance	Severity	Detection difficulty	Total ranking
1	Pilot's automobile	Engine refuses to start	Poor maintenance	Pilot marooned at private hunting lodge with no other means of transport. Unable to get to airstrip at project site	2	1	3	6
2	New maintenance hangar	Floor over basement collapses during first aircraft engine exchange	Errors in floor loading calculations when hangar was built	Personal injuries Damage to engines Damage to aircraft Schedules disrupted	1	5	3	15
3		Floor over basement collapses during first aircraft engine exchange	Floor slabs incorrectly poured	Personal injuries Damage to engines Damage to aircraft Schedules disrupted	1	5	2	10

Figure 17.10 Tiny part of a FMECA matrix for a new municipal airport project

RISK REGISTER

When all the known risks have been listed, assessed and ranked it is time to consider what might be done about them. That process requires that all potential risks in aviation projects be listed in a risk register (or risk log). A fairly typical example of a risk register page is shown in Figure 17.11 and it should be apparent that this is modeled closely upon the FMECA method demonstrated in Figure 17.10. However, the risk register has the following noticeable additions:

- an ID number for each risk listed;
- space for writing in the proposed action that would be taken should the risk event materialize;
- a column headed ‘Action by’ in which the name of the person or manager responsible for taking action for each risk can be entered. That person might sometimes be referred to as the risk owner

The risk register should be reviewed and updated regularly throughout the life of the project. It is advisable to use the computer to sort the risks according to their ranking, with the highest ranked risks placed at the top.

Risk ID	Date registered	Risk description and consequences	Probability P = 1-3	Impact (severity) S = 1- 3	Detection difficulty D = 1-3	Ranking P × S × D	Mitigating or avoiding action	Action by:

Figure 17.11 Example of a format for a risk register (or risk log) for an aviation project

METHODS FOR DEALING WITH RISKS

When all the known risks have been identified, assessed, ranked and registered it is time to consider what might be done about them. These are the decisions that must be entered in the two columns at the right-hand side of the risk register. The project manager usually has a range of options:

1. **Avoid the risk**—The only way to avoid a risk is to abandon the possible causes, which could even mean deciding not to undertake a project at all.
2. **Take precautions to prevent or mitigate risk impact**—This is a most important part of risk management, requiring the active participation of all managers and staff. It needs high-level risk prevention strategy combined with executive determination to ensure that all preventive measures are always followed throughout all parts of the organization. It requires the creation of a risk prevention culture, covering all aspects of project tasks, health and safety and consideration for the environment. Here are a few examples of the many possible practical measures, listed in random sequence:
   – provision of marquees for VIPs at an airport in case of rain during the inaugural celebrations for a new or rebranded airline;
   – regular inspection and testing of electrical equipment to ensure safe operation;
   – double-checking to detect errors in design calculations for vital project components or structures;
   – provision of back-up electrical power supplies for vital operations, essential services and computers (very important in all aspects of ground and flight operations);
   – frequent back-up and secure offline storage of business data;
   – avoidance of trailing electric cables in offices;
   – ensuring that means of escape routes in buildings are always clear of obstructions and that smoke screen doors are kept closed;
   – regular fire drills, testing of fire alarms and emergency lighting;
   – ongoing safety and emergency training for all flight operations and ground operations staff;
   – on-the-job training of back-up or seasonal staff to understudy key roles in the organization;
   – regular inspection and maintenance of vehicles such as push-back trucks and baggage trailers;
   – provision of safety clothing and equipment to protect workers and crew members, and enforcement of their use;
   – restricted access to hazardous areas;
   – provision of clear safety markings on all aircraft;

– adequate and ongoing training, above the minimum regulatory standards, for all those operating potentially hazardous equipment for ground or flight operations;
– regular financial audits and the installation of procedures to identify or deter fraud;
– and so on, and so on: this list could be very long.

3. **Accept the risk**—Rain might make the day chosen for office relocation miserable for all concerned but the risk would have to be accepted. There are numerous small things that can go wrong during the course of any project, and most of these risks can be accepted in the knowledge that their effect is not likely to be serious, and that they can be overcome by corrective measures or replanning. For example, an airline launching an inaugural service might have to accept a risk of short-term teething problems at an international destination arising from the employment of third-party service providers that are not accustomed to the airline's practices and standards.
4. **Share the risk**—If a project, or a substantial part of it, appears to carry very high risk, the contractor might seek one or more partners to undertake the work as a joint venture. Then the impact of any failure would be shared among the partners. Sharing a risk big enough to ruin one company might reduce its impact to little more than a temporary inconvenience. Risk sharing of this nature is common in aerospace manufacturing projects. Boeing and Airbus, for example, rely on a multitude of suppliers located around the world in the realization of their various projects. Hence, suppliers, depending on their position in a specific project, share in the risk of project delay or failure. For example, Airbus places 46 per cent of its aircraft-related procurement with suppliers across the US and Canada, <http://www.airbus.com/en/worldwide/north_america/us_indus_partners> (accessed 20 January 2008).
5. **Limit the risk**—There are occasions when project risks should only be accepted with safeguards in place to limit their potential effect. A good example is an internal project, perhaps for pure research, that cannot be adequately defined at the outset. No one can tell how much the project will eventually cost or what its outcome might be. Yet the opportunities are too great to consider avoiding the risk altogether.

The usual solution to starting an ill-defined project is to limit the risk by authorizing work step-by-step. It may be possible to divide the project into a number of stages for this purpose: indeed the process is sometimes called stage-gating. The stages might be determined by:

– the occurrence of significant events in the project that can easily be recognized when they happen;
– the imposition of a time limit for each stage;
– budgetary limit for each stage;

or

– a combination of any two or all of these.

Funding or authorization of expenditure on each new stage of the project would depend on a critical review of the work carried out up to the review date, coupled with a fresh appraisal of the value of continuing with the project. This approach has the advantage of limiting the committed risk. Although it is not possible to define the entire project in advance, it should be possible to look the short way ahead necessary to define each new step. Each limited step so defined may then be amenable to the project management procedures that cannot be used for the whole project.

In the step-by-step or stage-gate approach it always has to be borne in mind that it might become necessary to abandon the project at any stage and write off the expenditure already incurred. The aviation and defense industries have a long history of abandoned projects. A spectacular example worth mentioning here (although it happened 50 years ago) is that of the Bristol Brabazon in the UK. This very large and heavy turboprop aircraft was impressive for its time and won public praise, but the project was abandoned for commercial reasons after a successful maiden flight that was watched by a large crowd of enthusiastic spectators. Another British project abandoned after several test flights was the very advanced and promising TRS2 strike aircraft, on which the plug was pulled largely for political reasons.

6. **Transfer the risk**—Some risks, or substantial parts of them, can be transferred to another party on payment of a fee or premium. This leads to the important subject of insurance, which is discussed next.

INSURANCE

The Basic Principles of Insurance

The fundamental principle of all forms of insurance is that premiums paid by the many will pay for losses incurred by the unfortunate few who suffer a loss. A portion of the premiums paid will cover the cost of running the insurer's business, expenses and commissions and, together with any investment income, provide a profit and return on the capital employed.

The financial impact of many risks can be offset by insuring against them. The client pays the insurance company a premium for this service and the insurer might itself choose to spread the risk by sharing it with one or more other insurance companies. Figure 17.12 shows that managers do not enjoy complete freedom of choice when deciding which risks should be included in their insurance portfolio.

The policyholder (or potential policyholder) should be given all the necessary information before the inception of insurance cover, to assist him or her to arrive at an informed decision. In addition, the actual policy wording, terms and conditions must be available and agreed before inception to achieve 'contract certainty'. In plain English, that means that the intending policyholder must know exactly what will, or will be not, covered by the insurance, together with details of the cost.

Categories of Insurance

There are four main classes of insurance:

1. legal liabilities: payments to others as a result of statutory, contractual or professional commitments, compensation awarded by the courts, legal expenses, but not fines imposed by the courts;
2. protection against loss or damage to property, including temporary works and work in progress, owned construction plant, hired-in plant and employees' effects;
3. cover relating to personnel;
4. pecuniary loss.

A policy may combine cover for two or more of the above classes of risk.

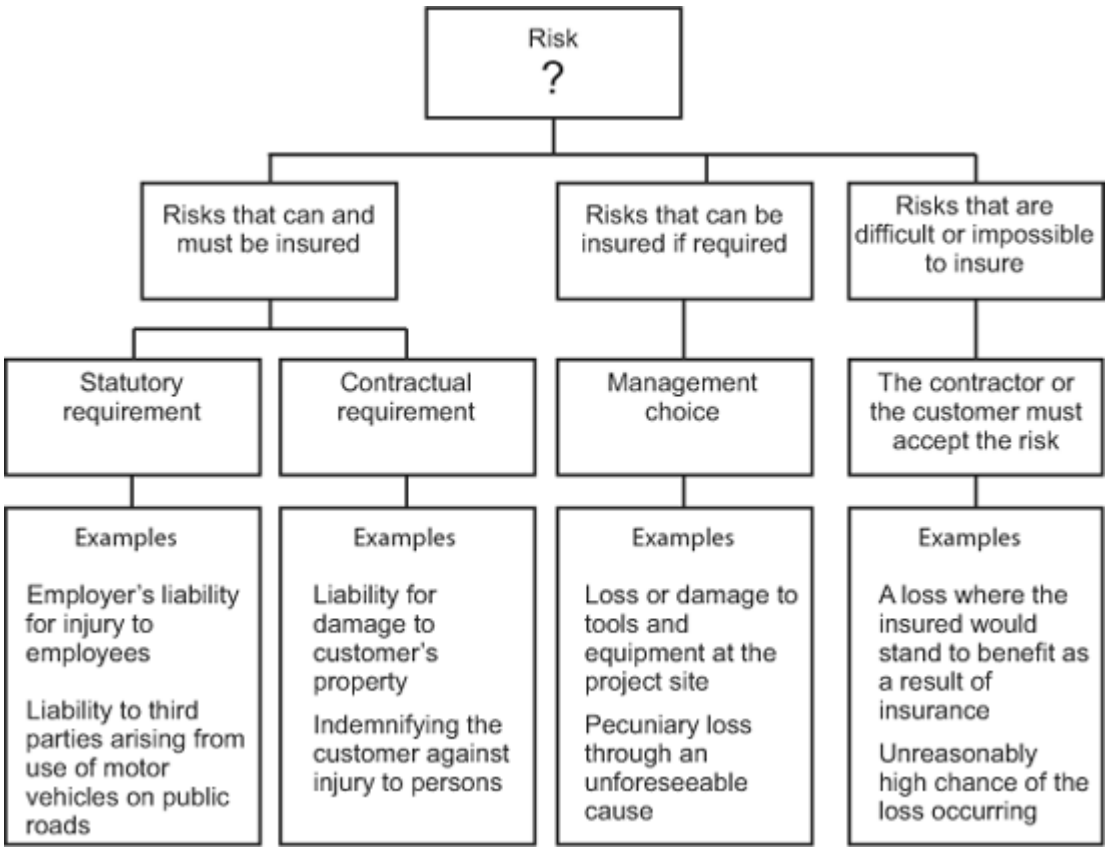

Risk
?
Risks that can and must be insured
Risks that can be insured if required
Risks that are difficult or impossible to insure
Statutory requirement
Contractual requirement
Management choice
The contractor or the customer must accept the risk
Examples
Employer's liability for injury to employees
Liability to third parties arising from use of motor vehicles on public roads
Examples
Liability for damage to customer's property
Indemnifying the customer against injury to persons
Examples
Loss or damage to tools and equipment at the project site
Pecuniary loss through an unforeseeable cause
Examples
A loss where the insured would stand to benefit as a result of insurance
Unreasonably high chance of the loss occurring

Figure 17.12 Risk and insurance in project management

Obligatory Insurances

Legal requirements oblige companies to obtain adequate insurance cover against some risks. These obligations arise either from various government laws and regulations or from conditions contained in a binding commercial contract.

Statutory requirements At the top of the insurance shopping list are those items which must be insured in order to comply with laws and regulations. Third-party insurance for motor vehicles used on public roads is a familiar example. Employers are obliged to insure their employees against injury or illness arising from their employment (Employers' Liability Insurance) and every employer has to display a valid certificate on its notice boards to show that such insurance exists.

Statutory regulations of particular interest to the manager of construction and engineering projects cover the periodic inspection and certification of

lifting equipment, pressure systems and local-exhaust ventilation plant. No project which includes the installation of such equipment should be handed over to a client without the relevant written (or other) scheme of examination and the accompanying inspection certificates. If the correct documentation is not supplied, the client will not legally be able to operate the equipment.

In the UK these statutory regulations form part of the Health and Safety at Work Act 1974. Much of this legislation resulted from European Directives and similar legislation has been enacted in other EU member countries. The principal European regulations are:

- Lifting Operations and Lifting Equipment Regulations 1998 (LOLER).
- Provision and Use of Work Equipment 1998 (PUWER).
- The Management of Health and Safety at Work Regulations 1999.
- The Pressure Systems Safety Regulations 2000 (PSSR).
- Control of Substances Hazardous to Health Regulations 1998 (COSHH).
- Electricity at Work Act 1988 (E@W).

Similarly, in the United States, the Occupational Safety and Health Administration (OSHA) which came into being in 1971, aims to ensure employee safety and health. US Congress created OSHA through the Occupational Safety and Health Act of 1970.

Inspection work is usually performed by engineer-surveyors employed by an engineering insurance company. The insurance company is sometimes engaged by the contract principal, but more usually by the main contractor. The larger of these insurance companies, with many years' experience of such work, are able to advise on compliance with national and local legislation covering equipment and construction materials.

The project manager of an airport construction or expansion project must check that inspection certificates required by the regulations are current and valid for plant hired for use on the airport. This will help to protect the project manager's organization from any liability that might arise from the use of a plant hire fleet that has been poorly managed by the plant hire company. Failure to comply with these, and other, regulations may have an adverse effect on the insurance cover. In addition, non-compliance could render the parties liable to prosecution.

Contractual requirements and other legal liabilities In commercial and industrial projects, whether for airport construction or aviation manufacturing, it is certain that some onus will be placed upon the parties (usually the contractor) to insure against several risks. All the model terms of contract for engineering, civil and construction contracts embody such requirements. The project contractor will also wish to make certain that sub-contractors are bound, in turn, by similar conditions.

Liability insurances are most likely to feature prominently in project contracts. The project purchaser will want to know, for example, that the contractor has adequate cover for legal liability in the event of personal injury, illness or death caused to anyone as a result of the project.

In summary, liability insurances may be required for:

- compensation to persons for bodily harm (employees of either party, others working on site, visitors and members of the public);
- property loss or damage, including work in progress;
- financial loss;
- infringement of property rights;
- accidents;
- product liability (arising from use of a product);
- professional negligence;
- nuisance caused by the works;
- environmental damage.

Every organization or professional person with project responsibility (including architects, consultants, surveyors, designers and project management organizations) must make certain that they have adequate professional liability insurance to cover any liability that they might incur in the course of their work.

Other Risks that can be Covered by Insurance

In addition to the statutory and contractual requirements, there is a range of other risks against which a contractor might be required to insure, or for which a contractor might decide that insurance is prudent. Some of these are listed below.

Contractors' all risks insurance for construction and engineering projects All risks insurance cover provides protection during the works, until the project is complete and handed over to the customer. Thereafter, insurance becomes the customer's responsibility.

All risks policies typically protect work in progress and temporary works against fire, storm damage, theft and malicious damage but any new policy proposal should be studied with care, as it is likely to list exceptions. In addition to work in progress, the cover should include loss or damage to:

- construction plant and machinery;
- hired plant;
- construction materials in transit to site;
- temporary buildings and site huts;
- employees' tools and effects.

In addition there will be other, minor, extensions of cover built into the policy for little or no extra cost.

Reinstatement costs after an accident will also be covered, including the costs of removing debris and the fees of architects, surveyors and consulting engineers. The insurer might also agree to pay additional expenses (such as overtime costs and express carriage rates) incurred as a result of expediting reinstatement work.

Contract all risks (CAR) policies usually apply to civil engineering and construction projects, while the less common engineering all risks (EAR) policies are for contracts that relate specifically to the construction and installation of machinery.

Exclusions and conditions in the policy, and in the policy schedule, should be examined carefully and understood before the insurance is entered into.

Decennial (latent defects) insurance Decennial insurance, which can cover a period of up to ten years, is designed to insure against damage to premises caused specifically by an inherent defect in the design, materials or construction of a project. In the event of a successful claim, decennial insurance removes the need for the project owner to suffer the expense of taking legal action for recompense against the contractor.

Accident and sickness insurance Provisions for personal accident, sickness and medical expenses insurance will need particular consideration when employees are required to travel, whether at home or abroad. Those working on projects in foreign countries will expect to be adequately covered for the higher risks involved, and such cover will have to be extended to spouses and children if they are also allowed to travel.

Key person insurance Key person insurance offers various kinds of protection to an employer against expenses or loss of profits which result when illness, injury or death prevents one or more named key persons from performing the duties expected of them. Arrangements are flexible and policies can be tailored to suit particular circumstances.

Pecuniary insurance Pecuniary insurances are designed to protect a company against financial losses from a variety of causes. Risks that can be covered include embezzlement, loss through interruption of business and legal expenses. Advance profits insurance may be possible in some limited circumstances to provide cover for delay in receiving planned return on project investment caused by late completion of the project.

Of particular interest to contractors where business with foreign customers is involved is export credit insurance. In the UK, the Government's ECGD provides guarantees that can provide security against bank loans for large capital goods and long-term projects. The Export-Import Bank of the United States provides a similar service in the US, whilst most other industrialized companies have similar schemes. The contractor will be expected to bear some of the risk, although its proportion will usually be small. The security offered by credit insurance can be an important factor in obtaining finance for a project.

Risks Which cannot be Covered by Insurance

There are risks which an underwriter will either refuse to insure, or for which the premium demanded would be prohibitive. Such cases arise in the following circumstances:

- Where the chances against a loss occurring are too high or, in other words, where the risk is seen as more of a certainty than reasonable

chance. Examples are losses made through speculative trading or because of disadvantageous changes in foreign exchange rates.
- Where the insurer is not able to spread its risk over a sufficient number of similar risks.
- Where the insurer does not have access to sufficient data from the past to be able quantify the future risk.
- Where the insured would stand to gain as a result of a claim. Except in some forms of personal insurance, the principle of insurance is to attempt to reinstate the insured's position to that which existed before the loss event. A person cannot, for example, expect to benefit personally from a claim for loss or damage to property not belonging to him or her (property in which he or she has no *insurable interest).*

These items must, therefore, be excluded from the insurance portfolio. In some cases other commercial remedies might exist for offsetting the risks.

UNIQUE PROPERTIES OF AVIATION INSURANCE

Aviation insurance was already an incredibly complex and dynamic field before it was impacted by the terrorist atrocities in the US on 11 September 2001 (now usually referred to simply as 9/11). In the 1990s, some major airline risks were insured and reinsured with the involvement of hundreds or even thousands of insurers and reinsurers taking a share. But, currently the trend is for market consolidation, so that the number of participants has fallen significantly, although there would still probably be over a hundred participating insurers for any major airline's specific risk.

Several features of aviation insurance set it apart from other classes of insurance. Three significant features are:

1. the limited number of risks available to insure;
2. its small size;
3. its potential exposure to catastrophic events.

Size and Scope of Aviation Insurance

The main complication for aviation insurers is the relatively few risks available to insure. This is especially so if just airlines are considered. Airclaims (2004a) records that at the end of 2003 there were only 765 airlines worldwide, and they operated about 16 400 Western-built jet airliners. Airclaims (2004b) states that this number increases to 2207 airlines operating about 26 000 aircraft, if all airlines operating jet or turboprop-powered aircraft of 15 seats or more are included. However, the actual number of individual risks is significantly fewer, because several airline groups consolidate their insurance and purchase on behalf of all the members of the group. In addition, the exposure, in terms of fleet value (or indeed size of fleet) is dominated by a few very large airlines or groups of airlines, with the 20 largest accounting for well over 50 per cent of the total value at risk. The 100 largest airlines probably account for 90 per cent of the exposure (measured either by value or the passengers carried).

The aviation insurance market is relatively small compared with many of the other classes of non-life insurance. It has been estimated that the total gross annual premium for all aviation insurance business is currently about $7500 million and according to Viccars (2001) ‘aviation premiums represent approximately 0.1 per cent of the worldwide insurance market’. Viccars (ibid.) reports ‘it was said that the annual premiums for the [aviation] class were less than the annual plate glass insurance premium for the state of New York’. The aviation industry premium level is probably considerably smaller than, for instance, the annual premium for automobile insurance in a reasonably sized country.

However, ‘while aviation as a class has one of the smallest premium bases in the insurance industry, it has some of the highest potential catastrophe exposure’ (Viccars, ibid., p.xvi).

Particular Exposure to High Risk and Potential Catastrophe in Aviation Insurance Claims

Some new Boeing 747s are insured for over $250 million and many wide-bodied jets will be insured for more than $100 million each. Coupled with that, cover for passengers and for third-party liabilities will be bought, with combined single limits (CSLs) of $1500m or $2000m. The total annual gross premiums income for airline business can easily exceed $3000m, but clearly

there is the potential for a single loss of a fully laden wide-bodied passenger aircraft to account for perhaps as much as two-thirds of those total premiums.

Worse still, there is always the chance of a collision between two large passenger aircraft. In Tenerife, Spain on March 27 1977 two Boeing 747 airliners collided at Los Rodeos (TCI) airport with 583 fatalities. To date, the Tenerife accident has produced the highest number of lives lost (excluding ground fatalities) of any single accident in aviation history. The aircraft involved were Pan American World Airways Flight 1736 and KLM Royal Dutch Airlines Flight 4805. KLM 4805, taking off on the only runway of the airport, crashed into the Pan Am aircraft which was taxiing in the opposite direction on the same runway.

In 1996, the Lloyd's insurance syndicate introduced a number of Realistic Disaster Scenarios (RDS). Lloyd's Syndicates have to demonstrate their capability to meet all their commitments, which might arise from these prescribed scenarios, if they are to continue to do business in Lloyds. There is currently only one RDS which specifically addresses aviation risks. This RDS, titled 'Aviation Collision' initially ran as follows:

'Assume a collision between 747s of the syndicate's two highest airline exposures occurring over a major US city; Assume liability loss of US$1 billion per airline' (Lloyds, 1997).

This assumed 'liability loss' has more recently been increased to a total of $4 billion, along with other changes (Lloyds, 2004). An actual occurrence of this scenario would produce a loss equivalent to more than 130 per cent of the 2003 gross premium income from all airline business worldwide.

With the exception of 9/11 (where the incurred loss falling on aviation policies exceeded $4.3 billion) there has been no aviation loss at the time of writing which has approached these levels. Nevertheless, in any one year, while there are relatively few total losses and/ or fatal accidents, there is always the potential for a 'catastrophe'. With a small premium base and occasional catastrophic losses, the airline insurance market can be very volatile.

OBTAINING PROJECT INSURANCE

Insurance can be sought directly from an underwriter, or through a broker; preferably one with a good reputation and experienced in the insured's type

of project activity. The insurer will need to be supplied with sufficient information for the risk to be adequately defined, and the contractor will be expected to inform the insurer of any change of circumstances likely to affect the risks insured. The insurer may wish to make investigations or even follow up the project work using its own experts.

Professional advice from insurers can often be of great benefit in reducing risks, especially in the areas of health and safety and crime prevention.

Two events in 2001 had a severe impact on insurers and will affect reinsurance and capacity for many years to come. One of these events was the insolvency and collapse of Independent Insurance plc, a company that insured a large number of contractors and construction trade clients for very low premiums. This caused every insurance company and broker to conduct internal audits, critically re-examining the risks to their own businesses. The other 2001 event was, of course, the 9/11 terrorist atrocities in the US which we have already mentioned, and which highlighted to insurance and reinsurance companies the potential for such enormous claims to be repeated in the future, whether from terrorist attacks or other causes. Insurers have since sought to limit their exposure to such risks and they have instituted a regime of stricter underwriting controls and lower risk acceptance thresholds.

Liability insurance is becoming expensive. Employer's liability cover, even though a legal requirement, is becoming difficult to obtain. Some insurance companies have had to close because they are unable to effect such insurance.

It is, therefore, now more important than ever for a project manager to involve an insurance specialist at a very early planning stage, lest he or she should find that no insurance cover is available at short notice.

PLANNING FOR CRISES AND EMERGENCIES

Some risk events can have such a potential impact on a project that special crisis management contingency plans must be made. Such contingency plans can extend to projects that would need to be set up specially and rapidly to deal with a sudden crisis, for example in areas that are particularly liable to epidemic diseases, famine, flooding, hurricanes, earthquakes or other natural disasters. Crisis contingency plans should also be put in place by process

industries and other companies that carry out operations which, if they should go wrong, could be hazardous for people and the environment beyond the factory gates. Aviation is clearly an industry in which crisis and emergency training has to be taken very seriously and regularly implemented. One cannot always say when or where a disaster will strike, but at least plans can be put in reserve to be implemented immediately when the need arises.

Organization

Once the possibility of a crisis has been established, the first step in devising a contingency plan is to identify the key people who will take charge should the event occur. These people will constitute a sleeping organization, ready to awake at a moment's notice in case of need. The core organization might include senior representatives of local and national government, the emergency services, particular charities and relief organizations, and so on. Each person should have the authority to instruct others within his or her home organization and the permission to identify the relevant resources that could be made available should the crisis happen. A team leader or steering committee must be appointed that will manage the project should it become live. This group of key people might be called the crisis action committee.

Contingency Planning

Once the key people have been elected or selected to serve on the action committee, they must meet to design appropriate contingency plans, and then meet again at regular intervals to ensure that the plans are kept up to date. The committee might have to arrange for emergency funds, stores and special equipment to be stockpiled or at least located against the time when they might suddenly be needed. Lists of secondary organizations and other helpers must be established, which although not part of the action committee could be called upon to give urgent and immediate assistance. These secondary associations might include, for example, specialist engineering or chemical contractors, explosives or decontamination experts, building and demolition contractors, caterers and a wide range of charitable organizations that could offer relief services. There might also be a need to plan for immediate advertising in the appropriate media to make public appeals for funds.

Tabletop and Other Exercises

One thing that the action committee will need to do as early as possible is to assess what might happen should the crisis arise. The committee will need to use their collective imagination to consider and be prepared in advance for as many of the problems as possible.

A tabletop exercise can contribute to this process, where the members of the action committee carry out a role-playing exercise to consider as exactly as possible what might happen and what they themselves and their subordinates might do should the crisis happen.

Many crisis contingency plans can be tested by field exercises, in which some or all of the services act out their parts as if the crisis had actually happened. Field exercises can reveal shortcomings in the contingency plans and test vital aspects such as mobility, response speeds and how to communicate and coordinate the various participants under emergency conditions, when power, water and telephones might all be out of action.

When the plans have been made and tested they must be documented, incorporating all the lessons learned from tabletop and field exercises so that they are ready to put into action effectively and with minimum delay. This is, in effect, creating a project handbook or project manual for a project that might never happen. When a crisis does cross from imagination to reality, however, contingency planning can save time and many lives.

Training of air and ground crews to ensure their effective response to a range of possible emergencies is routine in all well-managed airlines and airports. To give an example, all crews of passenger aircraft will receive training in the safe and rapid evacuation of passengers when an emergency occurs on take-off or landing. That training must be backed up by exercises in simulated emergency conditions, such as the existence of smoke in the cabin, or a reduction in the number of escape doors/emergency chutes owing to fire or crash damage. The training must be refreshed at regular intervals (perhaps every six months) so that crews will always be ready and trained to respond to a crisis. We cite just two of many examples to demonstrate how such training can save lives.

British Airways flight BA038 from Beijing (a Boeing 777) had 136 passengers onboard and 16 crew when, as widely reported by the media, both engines lost power late into final approach at London Heathrow in January 2008. The co-pilot (who was the handling pilot at the time) glided

the aircraft for two miles to clear residential housing, a busy motorway and (by only 20 feet) the airport perimeter fence. That remarkable skill had been enhanced through regularly training for just such emergencies on a flight simulator. In the actual event, the aircraft came to rest at the front edge of the runway after skidding for thousands of feet on grass. With the undercarriage torn away, wings badly damaged and fuel spilling out, the cabin crew used well-rehearsed procedures to evacuate all the passengers without serious injury. Equally well-rehearsed ground fire crews were quickly on hand to spray foam over spilt fuel and the hot engines to prevent fire.

At Toronto in 2005 there was an even more dramatic case where disaster was prevented by the crew of an Air France Airbus A340. This aircraft attempted to land during a severe thunderstorm, with torrential rain reducing visibility and impairing braking efficiency. The approach was too high and touchdown occurred 3800 feet down the drenched runway. The aircraft was traveling at 80 knots when it ran out of runway and skidded to rest in a ravine, where it caught fire. Yet, although there were some serious injuries, the Air France crew of 12 evacuated all 297 passengers without loss of life. That kind of escape from disaster can only be achieved through high professionalism which, in turn, depends on regular and well-organized crisis or emergency training exercises.

In many industrial and management projects risk management is regarded as an important yet academic aspect of project management that some do not take seriously. In aviation projects, risk management is at the heart of projects and safe operations.

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18
Contracts and Terms of Payment

Many aspects of contracts and commercial management are highly specialized and these are areas where it can be dangerous for the layperson to venture without professional help. Aviation projects tend to cross borders, with many international partners and some of those partners will have their own ideas about what constitutes a normal kind of sales or service contract. However, it is possible to outline some of the more important principles.

CONTRACTS

There might be many kinds of contracts made with or within a large project organization. For example, every employee should have a contract of employment. Clearly there will be a contract between the main contractor of a project and its external customer or project owner. Within each such project further contracts will exist between the main contractor and all the sub-contractors involved in providing goods or services. Every purchase involves a buyer-seller contract, usually embodied in a purchase order.

Even for internal investments such as R&D or management change projects a contract of some sort exists between the company and the staff member who is assigned to manage the project. At one extreme such contracts can be part of a very formal charter and contract form of project authorization. At the simplest extreme the contract might comprise a memorandum from a senior company manager to a more junior manager that specifies the work required and authorizes it to start.

Many professional institutions publish their own recommended standard forms of contract that are used commonly throughout a particular industry, such as construction, chemical engineering or electrical power projects. Aviation projects are often international in nature, and involve contracts between parties accustomed to different national ideas of what constitutes a contract. There are sometimes accusations made of payments changing hands

to induce companies to enter into contracts (bribes in common parlance), an arrangement that is considered the norm is some countries but would be illegal in others. Thus the subject of detailed and specific contract conditions is a minefield, which we shall not enter.

Therefore, after outlining the usually accepted conditions for testing whether a legal contract exists or not between two parties, this chapter will deal with three principal aspects of contracts as they are likely to affect the project manager, which are:

1. terms and conditions of payment;
2. contract variations (changes);
3. contract administration.

We should always keep in mind the significant regulatory footprint of the aviation industry that contains the pre-conditions for any contract composition. Of course legal frameworks and ensuring contract compliance with them is true for projects in any industry but safety (and in some cases commercial regulation of air transportation) add extra layers of understanding for those negotiating and writing aviation contracts.

Essential Elements of a Contract

Although a legally binding contract can exist between two parties on the basis of a verbal agreement, for project management purposes it is usually assumed that the contract between parties (such as a client and a main contractor) will be in writing. This applies also to all contracts made between the project contractor and the sub-contractors and other suppliers of goods and services. Properly drafted written documents should ensure that all aspects of each agreement are available for subsequent reference, both for routine administration of the contract and as evidence should any dispute require resolution.

The contract documentation might be a purchase order, an exchange of letters, a contract specially drafted by an attorney or a standard form. It is assumed that any subsequent amendments to the contract will also be written on suitable formal documents.

Several conditions must be satisfied for a legally binding contract to exist. The following notes are a summary, and do not list the exceptions:

1. **Intention**—The parties must intend that the contract shall be legally binding on them. In project contracts this intention will be assumed unless the parties have specifically declared otherwise, in which case the contract becomes only a formal version of a 'gentleman's agreement'. Project managers are not likely to be concerned with this question of intention, except perhaps when problems arise with collective agreements between management and trade unions.
2. **Offer and acceptance**—The contractor (seller) must make a definite offer stating willingness to contract on specified terms, and the contract becomes legally binding on both parties when the customer (buyer) informs the contractor that the offer is accepted without qualification. The customer must communicate acceptance before the expiry of any offer time limit set by the contractor.

   It may happen that the picture becomes blurred as to what has been offered and what actually has been accepted. Therefore the offer must be defined by a specification that is as complete and up to date as possible, amended as necessary to take account of all changes agreed during negotiations.
3. **Consideration**—A contract must result in each party promising the other a valuable benefit. In projects, this usually means that one party promises to deliver certain goods, property or services by a specified date and the other promises to accept the goods, property or services and pay for them. Failure of one party to keep its promise can lead to action by the other for breach of contract.
4. **Capacity**—In general, if the offer made by a company falls outside the scope of its powers as set out in the objects clause of its memorandum of association, then the company has no power to make the offer and the contract is void (said to be *ultra vires*, or 'beyond the power').

Terms Describing the Parties to a Project Contract

In general this book refers to the two main parties in project contracts as the customer and the contractor, but many other terms are used in practice.

Terms describing the project purchaser Some people use the term 'owner' to mean the customer, but this can be misleading because there are several possible circumstances where the customer will not have immediate legal

title to the project. One example is where the project is being funded under a lease-purchase agreement, so that the finance house will be the initial legal owner. A few contractors adopt the confusing practice of calling their own internal project managers 'project owners', with the intention of stressing that the project managers 'own' responsibility for their projects until the completed work has been handed over to the purchasers (the real project owners).

When a project is passed on by the customer to a third party, the expression 'end-user' can be useful to describe the eventual recipient. For example, if an aircraft manufacturer delivers a new aircraft to the ABC airline against a purchase contract, but ABC then transfers the plane to its subsidiary XYZ Airways, ABC is the manufacturer's customer but XYZ Airways is the end-user.

The terms in most general use are 'customer', 'client', 'purchaser' or 'buyer' but the terms 'promoter' and 'employer' are occasionally seen. For simplicity, 'customer' is used in most cases throughout this book but 'client' is commonly preferred in projects involving construction or the supply of professional services.

Terms describing the project supplier The organization carrying out the project may be described as the 'contractor', 'vendor', 'manufacturer', 'supplier' or 'seller'. The terms 'main contractor', 'managing contractor' and 'management contractor' are used to identify an organization employed by the project purchaser for help in managing and fulfilling a project. These terms are not strictly synonymous and the generally accepted distinctions between them are as follows:

- A *main contractor* or *managing contractor* is a person or (more likely) an organization that accepts commercial risk and responsibility on behalf of the customer and directly employs other contractors (sub-contractors) to execute some or all of the work. A common arrangement is for the main contractor to carry out design work in its own offices and then engage and supervise sub-contractors to supply specialist trades to perform some or all of the work.
- A *management contractor* is a person or organization engaged by the project customer to provide professional assistance in planning, coordinating and supervising the work of other contractors.

Throughout this book we have used the term 'contractor' generally to mean the company or other organization that has entered into a contract to carry out all or most of the work required for a project.

However, for an in-house management change or IT project, the 'contractor' could be an internal department or senior member of the customer's own staff.

Independent consultants Independent consultants often figure in large contracts, and may be appointed to safeguard the interests of one party or the other (usually the purchaser). In most cases the consultant is either a professional organization or a suitably qualified person, often referred to contractually as 'the engineer'. Refer, for example, to the role of the professional consulting engineer in a contract matrix, which is described briefly in Chapter 8 and illustrated in the organization chart of Figure 8.8.

Contract Scope

Specifying the technical and commercial scope is part of the project definition process. The contract documents should specify, without ambiguity, the exact role that the contractor is required to perform. The purchaser and the contractor must both be clear on what is included in any quoted price or charging rate, and on what is excluded. At its lowest level, the contract scope might be limited to minor involvement by a company as a subcontractor. At the other extreme, a contractor could be completely in charge of a large project, with 'turnkey' responsibility for all the work (which means handing the project over to the customer only after completion and successful commissioning).

Abbreviations describing contract scope Abbreviations are sometimes used as a succinct way to describe the scope expected of a contractor for a building or item of plant. These terms relate specifically to the expected role of the contractor in work such as the following:

- building the initial project;
- handing over the project ready for immediate use (turnkey);
- training the customer's staff to operate or use the project;
- operating the project for the customer initially;

- operating the project for the customer in the longer term;
- providing maintenance services.

The following are commonly used abbreviations, especially in construction contracts:

BOOM:	Build—own—operate—maintain.
BOOT:	Build—own—operate—transfer airport ownership.
BOT:	Build—operate—transfer airport ownership.
BOTO:	Build—own—train—operate.
OMT:	Operate—maintain—train.
TK:	Turnkey.

In contracts for the supply of purchased goods and equipment another set of abbreviations in common use is provided by the International Chamber of Commerce. These are the 'Incoterms' that define where the responsibility for goods transfers from the manufacturer or supplier to the customer when goods are shipped. These are described briefly in Chapter 19.

CONTRACT PAYMENT STRUCTURES

There are many ways in which contractors and their customers agree payment arrangements for project work. The payment terms will typically depend on the following factors:

- Risk, uncertainty and any other factor affecting the accuracy with which the project can be defined, estimated and budgeted.
- The customer's intention to set incentives that might influence contractor's performance. These incentives are usually aimed either at

completion on time or at completion below budget, but they can also have a bearing on the standard of workmanship and quality. A penalty clause may be included in the contract as an attempt to limit failure in performance, the most common form being a penalty payment calculated according to the number of days, weeks or other stated periods by which the contractor is late in successfully completing the project.

Fixed- (or Firm) Price Contracts

A fixed-price contract is the result of the familiar situation in which one or more contractors bid for work against a purchaser's clear specification, stating a total price for all the works. The purchaser is able to assume that the contractor cannot, in normal circumstances, increase the price quoted. The offer to carry out a project for a fixed price demonstrates the contractor's confidence in being able to complete the specified project without spending more than its estimated costs.

In practice there are sometimes clauses, even in so-called fixed-price contracts, which allow limited price renegotiation or additional charges in the event of specified circumstances that may arise outside the contractor's control (national industry wage awards are a common cause).

Cost Reimbursable Contracts

There are, of course, many types of contracts which do not start with the inclusion of a known total fixed price. Most of these are 'cost reimbursable' contracts where the customer agrees to repay the contractor for work done against a prearranged scale of charges. These charges might be for certified quantities of work completed or for reimbursing the costs of labor time and materials used. The contractor will, of course, be expected to provide documentation, such as employees' timesheets and purchase invoices to back up claims for payment.

Cost-reimbursable contracts are usually preferred to fixed-price contracts by contractors in cases where the final scope of a project cannot be predicted with sufficient accuracy when the contract is signed or where the work is to be carried out under conditions of high risk. Projects for pure scientific research (where the amount of work needed and the possible results are completely unpredictable) would obviously be unsuitable for fixed-price

quotations. Many construction contracts for major capital works or process plants are subject to high risk, owing to site conditions, the weather or to political and economic factors outside the contractor's control.

Even in cost-reimbursable contracts, with no fixed prices to bid, managers have to decide the levels at which to set the various charging rates. It cannot be assumed that a contractor will charge all customers the same rates. Some customers will demand details of how the direct and overhead charges are built up, and will expect to negotiate the final rates before agreement can be reached.

In any contract where payment is related to agreed rates of working the customer will want to be assured of the veracity of the contractor's claims for payment. This might even entail access to the contractor's books of account by the customer or by auditors acting for the customer. In construction contracts based on payment by quantities, independent quantity surveyors can act for the customer by certifying the contractors' claims to verify that the work being billed has in fact been done.

Estimating accuracy might seem less important where there are no fixed prices operating but tenders for contracts with no fixed prices might have to contain budgetary estimates of the total cost to the customer, so that if a contract is eventually made the customer will know what funding has to be reserved. If these budgetary estimates are set too high, they can frighten a potential customer away, and the contractor stands to lose the contract to competitors. If the estimates are set too low, all kinds of problems could arise during the execution of the work, not least of which might be the customer running out of funds with which to pay the contractor. Any contractor wishing to retain a reputation for fair dealing will want to avoid the trap of setting budgetary estimates too low, especially where this is done deliberately in pursuit of an order. In any case, the presence of avoidable estimating inaccuracies must prejudice subsequent attempts at planning, scheduling, budgeting and management control.

Summary of Contract Types

Quoted prices or rates do not always fall entirely into the clear category of fixed price or cost reimbursable, often because one of the parties wishes to introduce an element of performance incentive or risk protection. Some contracts (compound contracts) incorporate a mix of these arrangements.

Others (convertible contracts) allow for a change from a reimbursable contract to a fixed-price arrangement at some pre-agreed stage in the project when it becomes possible to define adequately the total scope of work and probable final costs.

Some well-known options are summarized below, and Figure 18.1 gives a broad idea of the relationships between risk and incentives.

Fixed-price A price is quoted by the contractor (seller) and accepted by the customer for the work specified in the contract. The price will only be varied if the customer varies the contract, or if the contract conditions allow for a price increase to be negotiated under particular circumstances (for example, a nationwide wage award in the particular industry). Thus the contractor accepts all the cost risks and, provided that the customer does not make changes to the scope or specification, the contractor must itself fund any excess costs arising from underestimates, technical difficulties or other causes. Should the contractor realize, at some stage, that costs are rising well above budget, it can be argued that there might be a temptation to cut costs by skimping work and thus putting quality at risk. Thus it is claimed that fixed-price risks might induce a contractor to keep costs low at the risk of 'cutting corners' or otherwise not performing to the highest degree of quality.

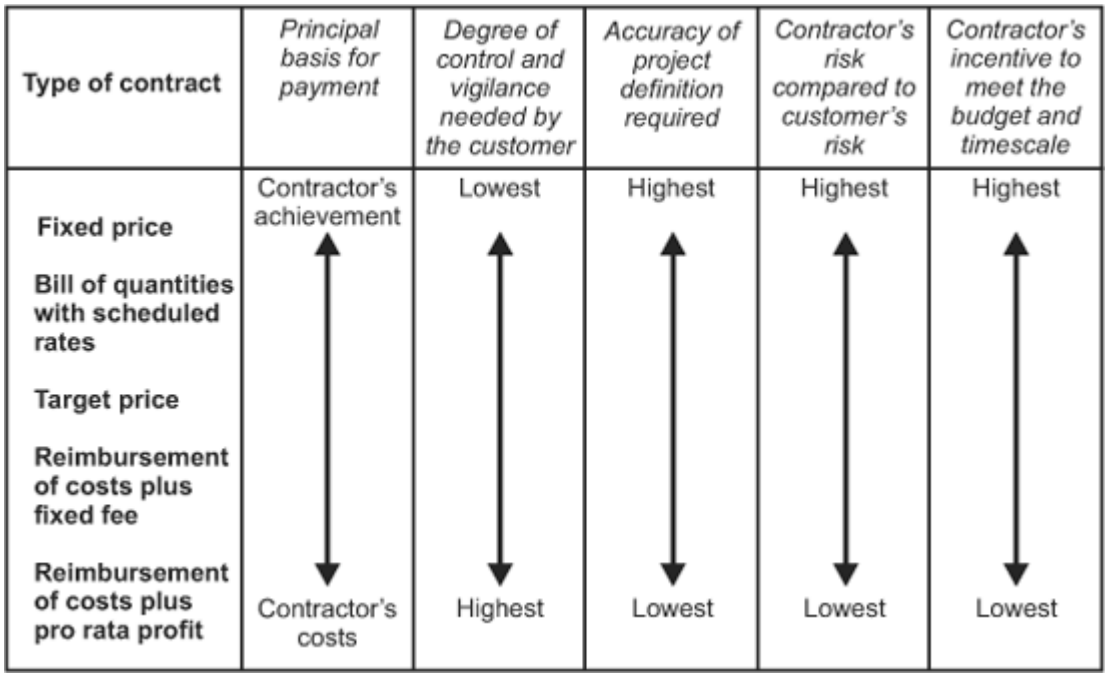


Figure 18.1 Relationship between payment terms and the control needed

Target-price Target-price contracts are similar to fixed price contracts, but they are used where there is some justifiable uncertainty about the likely costs for carrying out project as it has been defined. The contract allows for price adjustment if the audited final project costs either exceed estimates or show a saving, so that the financial risks and benefits can be shared to some extent between the customer and the contractor.

Guaranteed maximum price A guaranteed maximum-price arrangement is a target-price contract in which, although cost savings can be shared, the contractor is limited in the extent to which excess costs may be added to the target price.

Simple reimbursable A simple cost-reimbursable arrangement means that the contractor is reimbursed for the costs of labor, materials and other expenses, but is allowed no margin for profit. This type of payment sometimes occurs when work is performed by a company for its parent company, or for another company which is wholly owned within the same group of companies. A formal contract might not always be used in such cases.

Cost-plus Cost-plus is a common form of reimbursable contract. As in simple reimbursable contracts, the contractor charges for materials used and for labor time recorded against the project on timesheets. But the charging rates agreed with the customer are set at levels which are intended not only to recover direct costs and overheads, but are marked-up to include an element of profit.

Schedule of rates Contracts with scheduled rates are reimbursable contracts (usually cost-plus), charged according to the number of work units performed. A specific work unit charging rate will be agreed with the customer beforehand for each trade or type of work involved.

Reimbursable plus management fee This is a form of reimbursable contract in which the contractor's profit element is charged as a fixed fee, instead of being built in as a 'plus' element in the agreed rates. Unlike cost-plus, the contractor's profit revenue does not increase with cost but instead

decreases proportionally as total project costs rise. Arguably this provides an incentive for the contractor to keep costs low.

Bill of quantities with scheduled rates A bill of quantities contract is a form of reimbursable contract. It operates with an agreed schedule of rates, but the total number of work units expected in each trade or type of work is estimated and quoted beforehand.

THE TIMING OF PAYMENTS FOR CONTRACTS WITH EXTERNAL CUSTOMERS

Timing of Invoices for Fixed-price Contracts

Many large projects, spread out over timescales that might extend to several years, could involve the investment of large sums of the contractor's money. By the time the contract is completed and paid for, the resulting profit could be offset or nullified by the cost of the capital employed. In other words, the contractor has had to bear the interest costs (real or notional) on all money tied up in stocks and work in progress. For these reasons, 'progress' or 'stage' payments are often agreed between the contractor and the customer. This enables the contractor to raise some invoices during the course of the project. The contractor is not called upon to carry the whole cost of the project until completion and submission of the final invoice.

The basis for making stage payment claims may be cut and dried contractually, being dependent upon completion of certain stages in the project or on the deliveries of specified items of equipment to the customer. Standard contract conditions for various trade organizations may define the stage payment requirements. For example, a contract that we remember for the supply and installation of an elevator in an existing office building included the following non-negotiable payment terms, where the percentages given are calculated from the total contract price:

Percentage	When payable
10	Upon signing the contract (before the contractor actually starts work)
20	When the customer has approved the contractor's general design: this marks the point at which manufacture can start
30	Upon delivery of the main consignment of materials and components to the customer's premises
30	On handover of the new elevator to the customer after testing and commissioning
10	Final 'retention payment', to be withheld by the customer until the lift has given six months of satisfactory use or operation
100	

For many projects no such stages will be defined. Instead progress payments will be made at regular intervals, the amounts being decided according to a measurement of the actual work done (the amount of progress achieved). The customer will usually want to see evidence for such claims, and these are typically provided by certificates signed by an independent professional person. It is clearly important that such work achievement can be reliably measured or assessed to ensure that invoicing is kept in step with true progress.

Timing of Invoices for Cost-reimbursable Projects

Payments for day works or casual work using temporary agency staff may be invoiced at weekly intervals but most contractors will invoice their customers at regular calendar monthly intervals, either against certificates of work done, timesheets or other cost records that can be subjected to independent audit.

Cash Flow Implications

Most timing arrangements for payments are intended to protect the contractor's cash flow position, so that the contractor is not expected to invest large sums of money in work in progress over long periods for no return. Generally speaking, it is clearly the purchaser's responsibility to make sure that there will be sufficient funds to pay for the project. However, asking a contractor to commit large sums of money in work and purchases, but wait for payment until the project is finished and handed over, would effectively be expecting the contractor to assist the customer with project

funding. Cash flow management can make or break a company, and is so important that we have devoted Chapter 25 to the subject.

FINANCIAL VIABILITY OF PARTICIPATING ORGANIZATIONS

A sensible contractor will take steps to try and investigate the financial viability of any important new customer. Clearly no contractor wants to spend time and money on a project that fails because the customer runs out of liquid funds and is unable to pay the bills. The contractor might start by asking for copies of the customer's audited annual accounts and reports for recent years. This display of caution is usually reciprocal, so that customers often make similar inquiries of potential contractors. This kind of commercial research often extends to questioning the viability and business reputation of companies that will be expected to supply significant project materials, equipment and services.

Complementary processes can exist, therefore, where on the one hand a contractor wants to be assured that the customer will be able to meet all proper claims for payment, while the customer takes steps to ensure that the contractor is not likely to get into financial difficulties or even go bankrupt before being able to complete the project.

There are several ways in which these investigations can be conducted. Some companies make discreet inquiries themselves, asking other companies who have used the organization under scrutiny to provide references. To preserve anonymity, a professional organization such as D&B (formerly Dun and Bradstreet) can usually research information on a company's financial performance and status on a confidential basis (<http//:www.dnb.com>).

19
Purchasing—Part 1: Principles and Initial Ordering

This chapter discusses processes that take place before the purchase order for project goods and services. The subject is continued in Chapter 20, which moves on to aspects of purchasing and materials control that occur after the issue of a purchase order.

INTRODUCTION TO AVIATION PROJECT PURCHASING

Purchasing is a vital function of practically every project with aviation projects being unique in their technical nature for material requirements and, depending on the project, the relatively high price tags of purchases. Purchased goods and services typically soak up more than half the overall costs of a project, and that figure can be as high as 80 per cent in some cases. The efficient provision of equipment, materials and bought-out services is essential to avoid project delays through shortages, the acquisition of goods unfit for their intended purpose or serious over-expenditure. Competitive buying is important to the financial success of most projects. Overspending on material budgets can easily wreck profits. Yet, purchasing is usually denied its rightful prominence in project management teaching and textbooks. If you find this difficult to believe, take a trip to your nearest business library and browse through the project management books. You will find that many do not even mention purchasing in their indexes.

Cooperation Between the Engineering and Purchasing Functions

Purchasing deserves the best possible planning and management. It also requires close collaboration and trust between the project designers and

engineers on the one hand, and the purchasing organization on the other. That collaboration does not exist in all organizations. Occasionally, the engineers feel that their technical knowledge of project requirements equips them to be the best people to discuss all the procurement issues of materials and equipment with external manufacturers and vendors. Of course technical discussions are often necessary between engineers in the project organization and potential vendors. But when the time comes to make the commercial arrangements and enter into binding contracts the commercial skills of professional purchasing staff must be used. Otherwise engineers and other technical staff might commit their organizations to deals that are not in the best interest of their projects or their companies. So we stress that mutual trust and cooperation must be engendered between those who engineer projects and those in the purchasing organization who are charged with the responsibility for buying relevant materials, equipment and bought-out services.

Scope of Purchasing and Materials Management

In addition to the issue of purchase orders or contracts for services, the materials management function generally includes following up purchase order issues with expediting activity to help keep vendors reminded of their delivery dates. This order follow up can extend beyond the boundaries of the purchaser's premises to embrace supervisory expediting and inspection visits to vendors, making packing and transport arrangements for goods into and out of the firm, port and customs clearance for international movements, and expert involvement whenever special provisions have to be made for insurance, credit guarantees and other commercial arrangements. When the goods are received, it is usually the materials management organization that must check and inspect goods on arrival for non-conformances, clear invoices for payment and place the goods in secure storage.

Vendor rating is an important function of a purchasing department. This includes establishing lists of preferred vendors, based on their reputation and past performance. Another important aspect of vendor rating is assessing the financial viability of potential vendors to minimize the risk of a vendor going bankrupt before delivery of an order. It is easy to imagine the problems that such a failure could cause to work in progress and project finances. Vendor assessments are often made using the professional help of independent

inquiry agencies such as D&B (once more well known as Dun and Bradstreet).

THE PURCHASING CYCLE

Mainstream purchasing activities start long before an order is placed, and do not end until the materials have been delivered and put into store ready for use. Where international freight movements are needed, the purchasing department typically makes the arrangements, either directly or (more usually) by cooperation with a freight forwarding agent. Follow-up activities will be required if goods fail to match their specification upon delivery or in service.

The normal sequence of events for a significant project purchase is not unlike that of the project cycle shown in Figure 1.1. In fact, the procurement of any major item can be regarded as a mini-project in itself. The project manager is replaced in this analogy by the purchasing department or purchasing agent. Activities in the cycle vary somewhat according to the type of goods or services involved (especially their cost), but Figure 19.1 illustrates principal steps in a typical process.

REQUESTS FOR QUOTATIONS

The purchasing cycle is initiated by the discovery of a need for raw materials, components or a larger item of equipment. Clearly for small purchases it may not be necessary to call for competitive tenders, but the special safety and reliability requirements of the aviation industry will not allow technical or quality short cuts. For example, at an airport runway construction project, material required for the pavement would have to meet regulatory restrictions in terms of density and durability as well as environmental fit to be able to be useable. Therefore, a careful evaluation of design needs, and the regulatory requirements to fit those needs, is an absolute ‘must’ in regard to purchasing. Thus, once the need for each purchase has been recognized, action must be started by the project designers to write or obtain a specification which the purchasing department can pass on to the potential vendors. For low-cost items, this might simply accompany a purchase order. For higher-value purchases it will form part of a request for quotation (RFQ), also widely known as an invitation to tender (ITT).

Regulators are there to ensure safety and safety compliance, so their involvement starts with the issuing of standards and directives. Their involvement continues with auditing once projects are completed and with periodic audits during the operational stage to ensure compliance.

Continuing with the example of runway construction, the ideal arrangement is that the relevant engineering design department supplies the specification which sets out the performance and other physical properties expected, whilst the purchasing manager or buyer negotiates the commercial terms. Engineers will often have a preferred manufacturer or vendor in mind, but competent purchasing departments maintain lists of vendors from which they can solicit offers.

Unfortunately this ideal cooperation between the engineer, the buyer and (eventually) the vendor is not realized in some organizations owing to conflict between the design and purchasing departments. Some engineers will approach potential vendors directly, discuss technical solutions with them and then give a verbal commitment to order. Whilst the technical discussion part of this process is often desirable, it is far preferable for all binding contracts to be made via the purchasing department, which should be staffed with people having the essential commercial skills and negotiating ability. Contrary to some popular belief the role of the purchasing department goes well beyond simply issuing purchase orders. So we shall describe the ideal arrangement here.

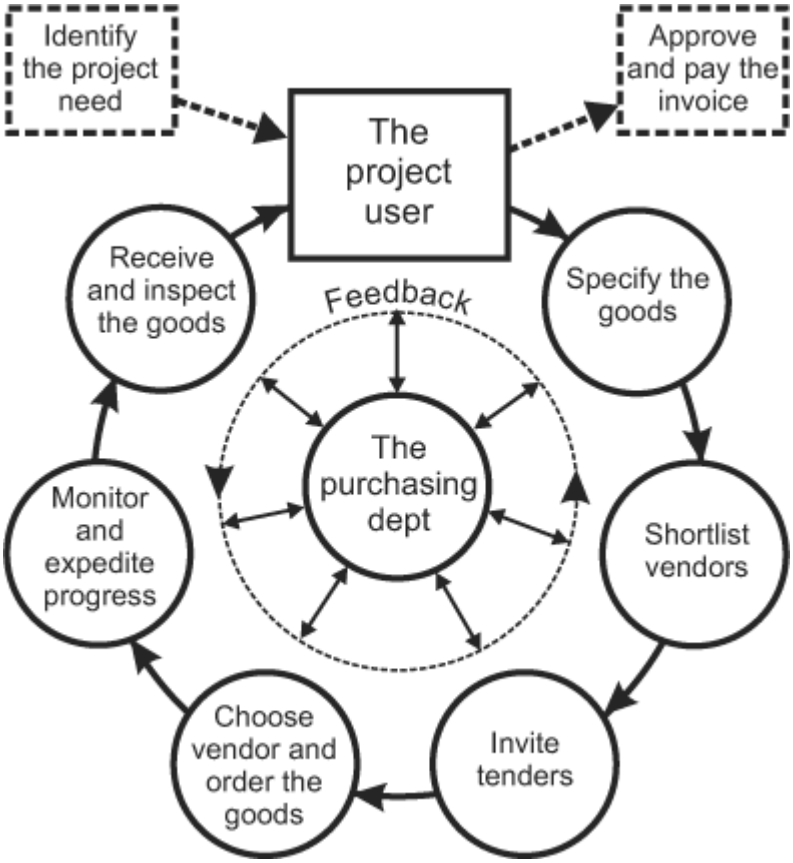


Figure 19.1 Purchasing cycle
Each significant purchase, especially for equipment with a high technological content, can be regarded as a project within the main project. It will have its own cycle (shown here). Compare this with the project cycle shown in Figure 1.1

So, to recapitulate, the engineering design staff will specify what is needed, and the purchasing department will then proceed to invite relevant bids. So each potential vendor will receive an inquiry letter or an ITT from the buyer, and that will set out the commercial expectations. A copy of the relevant engineer's specification will be included with every inquiry. Thus each inquiry can be considered as having two parts, which are the commercial part and the technical part.

The final choice of vendor in each case should be agreed jointly between the project manager or relevant engineer and the buyer. In projects for external clients, there are occasions when the client also wishes to be involved and to approve the choice of vendors for high-cost items.

BID RECEIPT PROCEDURES FOR HIGH-PRICED GOODS AND SERVICES

Sealed Bids

In a sealed bids procedure, all bidders are sent an identical ITT package that sets out all the technical and commercial aspects of the proposed purchase. A forward date is set for the submission of tenders, and that date is fixed so that late receipts will automatically be disqualified. The purchasing organization opens all bids on the due date, and then they are assessed so that the successful bidder may be chosen.

During the run up to the deadline for submission, one or more applicants might wish to ask questions, have certain points clarified or seek permission to depart from the specification in one or more respects. For example, one of us once received an ITT for a consultancy contract in which a very high level of professional indemnity insurance was specified. When that was queried, the level was reduced to one-tenth of the original demand. However, to maintain transparency and fairness, the purchaser sent every other bidder details of the request, and all were granted the same dispensation for reduced insurance requirements.

Sealed bid deadlines are rigid, so that any bid received after the due date should be either destroyed or returned to the sender. Thus the due date is something of an occasion, on which all the bid packages are opened and compared with each other by the purchasing manager, the project manager and other senior staff according to the requirements of the particular project organization.

Two-pack sealed bids Two-pack sealed bids are very similar to the single pack variety, except that each bidder is asked to separate the bid into two sealed packs. One pack details the technical response and explains how the vendor will fulfil the performance and quality requirements of the ITT. The other pack contains the bidder's terms of supply, including pricing.

On the date set for opening the bids, the purchaser opens all the technical bids first, and the best solutions are shortlisted. Non-acceptable solutions are discarded, along with their unopened commercial bid packages. Only then are the surviving commercial packs opened. Thus (it is argued) performance and quality will not be compromised at the expense of a cheap price.

Courtesy demands that every bidder receives a report on whether or not their bid has succeeded. The buyer is usually under no obligation to give reasons for the decision.

BID EVALUATION PROCEDURES

Whatever the bidding process, when bids are received from a number of different vendors confusion often arises as to what each quotation includes in its main price and what items are to be regarded as extras. Some vendors are expert in quoting prices that appear to be low, but which do not include so-called optional extras that are not really optional at all, but are essential to the adequate use of the materials or equipment. What the purchaser needs to know is the price expected for goods that will be fit for purpose at the project point of use.

Another complication arises in international purchases, where one vendor might be able to supply or manufacture the goods faster than its competitors but will lose some or all of that time advantage in the time needed to pack the goods and ship them across international borders. These international orders also attract the additional complications of export/import regulations and duties, packing and freight costs, and other handling charges. Foreign exchange rate variations are an additional factor.

Thus when comparing bids from several vendors it is necessary to bring them all to a common denominator of price and delivery, so that the project manager and buyer know when the goods are promised for delivery at the point of use, and also the total inclusive cost of getting the goods to that point of use.

The process commonly used to help resolve all these questions is known as a bid evaluation or bid summary procedure. This requires that summary data from the competing vendors are set out on a matrix format in which the prices delivered complete at point of use are clearly compared. Also compared are the total delivery times, from placing of order to receipt of the goods. Now the purchaser is better able to compare like with like. A compact bid summary form is shown in Figure 19.2. This illustrates the principles well but a larger format is often needed in practice to cope with the amount of detail to be considered. Of course in the real world things could be more complicated as personal relationships and personal likes or dislikes could circumvent the ‘textbook’ process. That could happen where

for scope or other reasons the process itself has not been structured in formal ways.

TERMS OF TRADE USED IN INTERNATIONAL BUSINESS (INCOTERMS)

When purchasing goods it is important that the boundaries of responsibility for transportation are clearly defined in proposals, contracts and on purchase orders. Incoterms, defined and published by the International Chamber of Commerce, are accepted worldwide as the succinct and definitive method for setting out these boundaries. The terms are listed below, in ascending order of the vendor's scope of responsibility. Full definitions of these terms are obtainable from the International Chamber of Commerce, which has offices in many places around the world. Incoterms are categorized as follows:



BID SUMMARY

SELLERS →			A	B	C	D	E	F
Country of origin								
Bid reference								
Bid date								
Period of validity								
Bid currency								
Project exchange rate								
Item	Qty	Description	Price	Price	Price	Price	Price	Price
Total quoted ex-works								
Discounts (if any)								
Packing and export prep cost								
Shipping cost								
Customs duty and tax								
Local transport cost								
Estimated total cost on site								
Delivery time ex-works								
Estimated total transport time								
Total delivery time to sit								

RECOMMENDED BY THE PURCHASING DEPT:

Chief buyer

RECOMMENDED BY THE PROJECT ENGINEER:

Project/ senior engineer

RECOMMENDATION TO THE CLIENT:

Project manager

Specification title:	Specification number:

Figure 19.2 A bid summary example

Group E Incoterms (departure)

EXW Ex-works

Group F Incoterms (main carriage unpaid)

FCA Free carrier

FAS Free alongside ship

FOB Free on board

Group C Incoterms (main carriage paid)

CFR Cost and freight

CIF Cost, insurance and freight

CIP Carriage and insurance paid

Group D Incoterms (arrival)

DAF Delivered at frontier

DES Delivered ex-ship

DEQ Delivered ex-quay

DDU Delivered duty unpaid

DDP Delivered duty paid

PURCHASE REQUISITIONS AND ORDERS

When the time comes to order goods from a chosen vendor, the procedure in many organizations is that the project manager (or delegated engineer) sends a request to the purchasing department in the form of a purchase requisition. This requests the purchasing department to place a purchase order with the agreed vendor and (as with the previous request for an inquiry to be issued) this should again be accompanied by a technical specification. Now the specification should exist in a more final form, because it must first be updated to include any changes made as a result of earlier discussions with vendors.

When placing an order for an item that is listed in a vendor's catalogue it can be argued that there is no need for the buyer to submit a specification, since the catalogue should list the physical characteristics of the item.

However, vendors usually publish escape clauses that give them the right to change the specification of an item without prior notice, or even to substitute alternative goods (usually claimed to be of at least equal or superior quality). In aviation projects especially the buyer and the project engineers must know exactly what to expect when the goods are delivered, and to that end attaching their own specification to an order (and making that specification a condition of contract) clearly safeguards the quality, reliability and safety aspects of each purchase.

National regulatory codes and directives exist that spell out these requirements very explicitly and buyers and engineers need to be keenly familiar with them. Even something as simple as replacing worn out seats in an aircraft must be done in with strict observation of safety regulations, in regard to such properties as seat weight and size, as well as material given weight and balance restrictions and requirements. With regard to the material itself, flammability grades, strength, electrical loading (if they are electrical) and fire safety requirements are all relevant. The purchasing management and the mechanics involved in the work must be thoroughly familiar with the regulatory cases and directives. Each country's civil aviation authority will oversee this process, whether a requirement for a safety management system approach exists or a more traditional regulatory compliance approach is appropriate. Depending on the type of operation (commercial versus general aviation) additional regulatory requirements exist that go beyond engineering work into the operational framework.

The foregoing applies particularly to special project purchase orders but other procedures will come into play to replace purchase requisitions when an R&D project moves from its prototyping phase to preproduction and full production. In those cases purchase orders can be raised by the purchasing department on the basis of information from routine production systems such as stock control records. However, those methods are outside the scope of this book because they are not generally associated with one-off aviation projects.

PURCHASE ORDERS

Moving one more step round the cycle for a major project purchase, the order has to be prepared and sent to the vendor (either by mail or electronically). This is the most routine and obvious part of the purchasing

cycle, usually consisting of typing or keying the order details, checking and signing it, and then transmitting it to the vendor by mail or electronically. What has this action by the purchasing department got to do with project management? One reason is that it is a task that must be included in the detailed project schedule because it takes time. Several days or even weeks of valuable project time can be consumed by this mundane, apparently simple activity. Procurement lead-time estimates on the critical path network must always allow for such delays. In fact, unless emergency measures are contemplated, two weeks should often be regarded as a minimum estimate for purchase lead-times, even for items that can be obtained from the vendor's stock.

The design of purchase order documents varies from one company to another, but every purchase order needs to specify the following information:

- a purchase order serial number, for identification, filing and subsequent information retrieval;
- the name or description of the goods to be supplied;
- the quantity required;
- the agreed purchase price, as quoted by the vendor and accepted by the purchaser;
- if relevant, the reference number and date of the vendor's quotation document or catalogue item;
- the delivery date required;
- the address to which the goods are to be delivered;
- the terms on which delivery are to be made (liability for transport, packing, insurance costs and so on);
- invoicing instructions;
- an authorizing signature.

Most companies develop standard conditions of purchase which they either supply with their purchase orders or print on the reverse side of the order form. Vendors are usually asked to accept these conditions and acknowledge that acceptance, often by means of a tear-off slip that they are expected to return. For electronic orders, the equivalent would be to click on an acceptance box.

Example of Standard Conditions of Purchase

We give here an example of a set of purchasing conditions printed on the reverse of every order by a company in our experience. Names have been changed to protect the identity of the company. Clearly this is only an example, and each company will consult its legal advisers on the terms appropriate for its particular business operations and the country or state in which it is located.

1. *Definitions:*
   Company—means The Dennis Aviation Company Limited.
   Seller—means the person, firm or company to whom the company's order is addressed.
   Goods—means the supply and delivery of the goods, materials or equipment in accordance with the company's order together with any subsequent modifications specified by the company.
   Contract—means the agreement between the company and the seller for the supply of goods.
2. *Payment:* Net cash against shipping documents or other proof of delivery unless otherwise agreed (subject to any deductions and retentions authorized in the terms of the order, and subject to the seller carrying out all its obligations).
3. *Prices:* All prices are fixed for the duration of the contract and, unless otherwise agreed, are not subject to escalation charges of any description.
4. *Quality and description:* The goods shall conform to description, be of sound materials and quality, and be equal in all respects to any specification given by the company to the seller.
5. *Indemnity:* The seller shall at its own expense make good by repair or replacement all defects attributable to faulty design and/or workmanship which appear in the goods within the period of 12 months from date of delivery. The seller shall also indemnify the company in respect of all damage or injury occurring before the above-mentioned period expires to any person or property and against all actions, suits, claims, demands, costs, charges or expenses arising in connection therewith to the extent that the same have been occasioned by the negligence of the seller, its servants or agents during such time as they were on, entering on to or departing from the company's premises for any purpose connected with this contract.

6. *Intellectual property:* The seller will indemnify the company against any claim for infringement of letters patent, trademark, registered design or copyright arising out of the use of sale of the goods and against all costs, charges and expenses occasioned thereby except in so far as such infringement is due to the seller having followed the design supplied by the company.
7. *Loss or damage:* All responsibility for any loss or damage, whether total or partial, direct or indirect from whatsoever cause, shall lie with the seller until full and complete delivery in terms of the order shall have been made by the seller. But it is agreed that the company will take all necessary steps to ensure that it does not in any way invalidate any claim which the seller may have against the carrier.
8. *Changes in the work:* No variation of, or extras to the order, shall be carried out by the seller unless specifically authorized by the company on its official amendment form.
9. *Sub-vendors:* The seller shall provide a list of all sub-contractors or sub-vendors when requested by the company.
10. *Expediting and inspection visits:* The company's inspection and expediting staff or appointed agent shall be given access at all reasonable times to the seller's works or offices or those of any sub-contractor to view and discuss work in progress.
11. *Rejection:* The company may at any time, whether before or after delivery, reject (giving reasons therefor) any goods found to be inferior, damaged or if the seller commits any breach of the order.
12. *Arbitration:* Any dispute or difference arising from the contract shall, on the application of either the seller or the company, be submitted to arbitration of a single arbitrator who shall be agreed between the parties or who failing such agreement shall be appointed at the request of either party by the appropriate judicial body.
13. *Time for completion:* The seller's promised delivery date must be firm, but if delivery is delayed through any cause beyond the control of the seller and immediately such cause arises the seller notifies the company in writing giving full particulars then a reasonable extension of time shall be granted. If delivery is not made within the time stipulated or within any extension of time the company shall be at liberty to cancel the

contract without prejudice to any right or remedy which shall have accrued or which shall thereafter accrue to the company.

14. *Title to goods:* Title to the goods passes to the company on delivery to the specified place of delivery as requested by the company.
15. *Law of the contract:* Unless otherwise agreed the contract shall be subject to the laws of [in here the name of the specific country would be inserted].

Order Acknowledgement and Acceptance by the Vendor

When the vendor has received the purchase order, complete with its set of conditions, the vendor is expected to acknowledge acceptance of the order. That then establishes a legal contract. Some purchase order forms carry a tear-off acknowledgment slip which is intended to encourage the vendor to accept the standard conditions and other requirements of the order. However, many vendors ignore such arrangements and acknowledge receipt of the order but supply their own set of standard conditions, which might differ from those of the purchaser.

It is possible for correspondence to develop, with each party to the contract continuing to send to the other the particular set of conditions that it prefers. In the event of a dispute it is then possible that the courts will regard the conditions contained in the last, unanswered letter of such correspondence as those which apply to the particular contract. The inference is that those conditions have not been rejected and have thus been accepted by default.

TIMING OF ORDERS AND DELIVERIES

Early Ordering of Long-lead Items

Engineers and others responsible for initiating project purchases have a duty to identify those items that are likely to have long lead times and ensure that ordering instructions are passed to the purchasing department as soon as possible. This might mean issuing advance information on such things as special bearings, motors, castings and other bought-out components, at times when the relevant assembly drawings and final bills of material remain unfinished or even not started. Even when the goods cannot be specified in

exact detail, this gives the purchasing department the chance to get started on obtaining provisional quotations and (in a really urgent case) on reserving capacity in a manufacturer's works by issuing a letter of intent.

Any company with sufficient project experience will attempt to follow such practices as a matter of course. If a project has been planned using a critical path network any need to issue advance purchasing instructions should certainly be highlighted.

Just-in-time

The phrase 'just-in-time' took on a specific meaning with the adoption by some companies of the Japanese approach to purchasing and manufacture which attempts to reduce stockholding to zero and, among other things, relies on vendors to deliver direct to the workplace 'just-in-time'.

This system relies heavily on establishing a great deal of trust, and the vendors are expected to be fully responsible for delivering the supplies in the right quantities, at the right time and of the right quality without day-to-day supervision from the purchaser. These ideals cannot be achieved overnight and require cooperation, partnership and trust between purchasers and vendors. Such partnerships, even with the best intent on both sides, take time to establish and are difficult to operate for project purchasing where regular use of vendors and repeat orders are not the norm.

As a general rule, it is late or incorrect deliveries (and the shortages which they cause) that will always produce the biggest headaches for project managers, and any decision to delay the issue of a purchase order must be tempered with caution, allowing time for unforeseen contingencies. What would happen, for example, if an important consignment arrived just-in-time, only to be rejected as being damaged in transit or was otherwise unfit for project use?

However, the tremendous advantages of reduced storage requirements and greatly reduced value of work in progress make this option a worthwhile pursuit for when R&D projects end and the company moves on to volume manufacturing and sales of the resulting product.

20
Purchasing—Part 2: The Supply Chain

This chapter continues where Chapter 19 left off, by dealing with purchasing activities that take place after the issue of a purchase order. Note that purchasing is also discussed briefly in Chapter 24 with relevance to project cost control, and in Chapter 25 in the context of cash flow management.

Logically the next activity in a typical purchasing cycle after issuing the order is monitoring and expediting, but to understand what that means it is first necessary to know a little about the complexity of the total supply chain. For some major purchases from foreign suppliers that supply chain can be long and complex.

SIMPLEST SUPPLY CHAIN ORGANIZATIONS

In describing what we understand by a materials supply chain we shall begin with the simplest case, and then we can move on to describe a very complex chain. These are the two extremes. By describing these we shall cover the possible elements of almost every supply chain and thus it will not be necessary for us to attempt descriptions and illustrations of the many variations that might exist between these extremes.

The very simplest supply chain possible is found when a member of staff is sent out to a local store to buy goods off the shelf, carry them back to base and recover the costs against petty cash. However, for practical purposes the most common simple case in aviation project purchasing is when a supplier within the same state as the purchaser is able to supply suitable goods from stock. This case is illustrated in Figure 20.1. Even this simple case involves three different companies, the purchaser, the supplier and the freight company.

Progress through the supply chain goes from left to right in Figure 20.1 and the supply chain can be seen to end when the materials or equipment are in place ready for use on the project. There might of course be subsequent spin-

off activities in connection with this supply. For example, when complex equipment is purchased there could be follow up activities from the supplier in training its customers in the maintenance and use of the equipment. There will also most likely be a warranty or guarantee period that extends the supplier's liability well beyond the delivery date. However, for practical project purposes in this chapter we need consider only those stages needed to process the materials up to delivery at their point of use on the project.

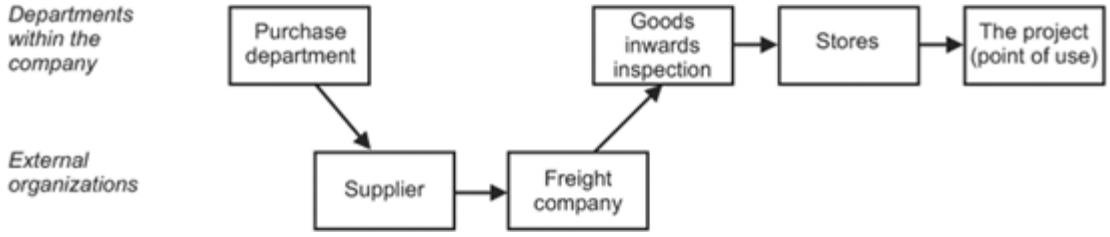


Figure 20.1 Supply chain for a simple purchase operation

COMPLEX SUPPLY CHAINS IN INTERNATIONAL PROJECT PURCHASES

Aviation projects usually have a strong international dimension, whether these are in flight operations or in the development of new products. Companies that regularly perform projects with international involvement take special steps to ensure that their interests are safeguarded in all the foreign countries involved. Thus they will ensure that a purchasing representative is placed in or near every foreign country from which project goods are likely to be sourced. If the company is part of an international group, this representation can often be provided through the medium of suitably located companies within the group. Otherwise good practice is to engage reliable professional agents in one or more key geographical locations.

There are companies that exist to provide purchasing services and advice to clients overseas, At their most comprehensive, such services can include obtaining quotations from local suppliers and, when orders have been placed, carrying out expediting and inspection visits to suppliers' premises on the purchaser's behalf. For example, an aviation company in North America that frequently purchases equipment from suppliers in France and Germany might have an agent appointed in Europe to deal with those

suppliers. The agent chosen would have technical engineers on its staff who could speak the local languages. Some of these agency arrangements work so well that the agent can be considered almost as an extension of the project company's own purchasing department.

Import and export regulations can be very complex in international trade. Some of the potential aspects that can be difficult for project companies new to this trade (or will completely confound project personnel with no commercial experience) include the following:

- embargos on specified goods (such embargos can be imposed for political or health reasons);
- complex invoicing arrangements (some countries require many copies of export invoices, printed on their own specified forms);
- arrangements with banks or insurers to ensure safe transit of cash, such as letters of credit and export credit insurance;
- port regulations and charges at both departure and arrival points of entry;
- customs and excise duties and inspections;
- professional export packaging to protect the goods;
- specified markings on packages and crates to avoid loss and assist identification at all points in the supply chain;
- transit arrangements from the supplier to the exit port;
- international transport by road, rail, ship or aircraft;
- customs clearance;
- final leg transportation by road, rail or air from the arrival port to the project user;
- security and traceability of every consignment of goods through all these stages.

Purchasing departments in very large aviation companies and some overseas agents might be competent to deal with some or all of these processes but many companies will employ an agent that specializes in the safe conduct of goods to protect their interests and reduce transit delays to a minimum. For light packages and documents, courier services (such as DHL) can be used. For really urgent shipments such as contract or proposal documents couriers can supply people who will accompany each consignment personally through all stages of their journeys. However, the

vast bulk of international shipments are carried out under the care of international freight forwarding companies.

Freight forwarders will usually arrange for sea shipments to be containerized to achieve maximum economy of shipping space. Confusingly for most landlubbers and project personnel, shipping tonnes generally relate not to the weight of the goods being conveyed but to the volume of space they will occupy on the voyage.

The most vital role of freight forwarders is made possible by their having offices or agents throughout the world, by means of which the progress of every shipment can be tracked through all its stages. Thus the possibility of loss is minimized. However, even the very best freight forwarder cannot always prevent delays through strikes, port congestion, bad weather, criminal activity and unreasonable officialdom by port and customs personnel. Freight forwarders usually own their own vehicle fleets, and so can carry out the local freight services themselves, either at the delivery end or at both the collection and delivery ends of the journey. Very large organizations such as DHL operate their own aircraft fleets.

There is one further complication that can apply to any supply chain, whether international or not, which is that the suppliers of some equipment will be dependent for their performance on their own sub-suppliers and sub-contractors.

Figure 20.2 sets out the possible configuration of an international supply chain, with the various organizations generally disposed from left to right in the sequence in which they are likely to become involved with a typical high-cost purchase.

EXPEDITING

Once each order has been placed, responsibility within the purchasing department moves from the buyer to the expeditor, although in smaller organizations the buyer will fulfil both roles. Contrary to popular belief, expediting is not just a process for chasing up goods which are overdue for delivery. It is a preventative measure that seeks instead to foresee problems and pre-empt late deliveries.

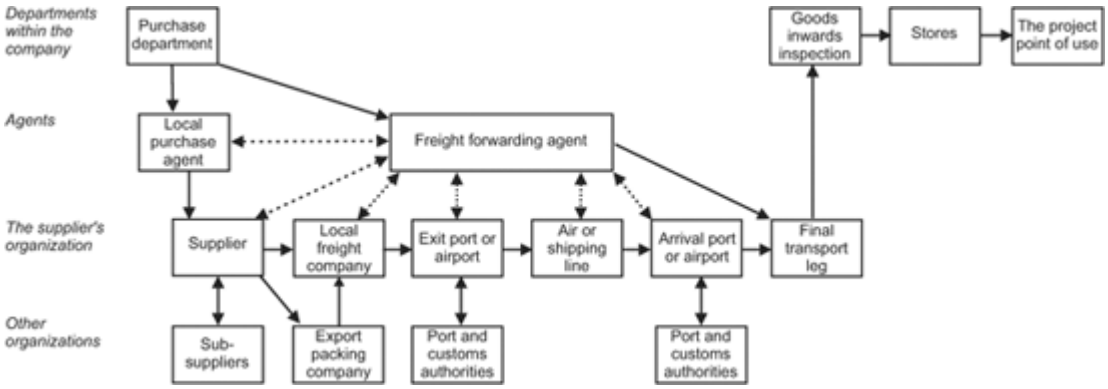


Figure 20.2 Possible supply chain for the international purchase of aviation project materials or equipment

Routine Expediting

Expediting is usually a routine procedure for monitoring the progress of each order, so that suppliers can be encouraged to deliver on time, and to allow adequate warning of any possible delay.

One expediting method consists of marking each purchase order record in the computer (card index in old fashioned systems) to flag the dates when reminders to the supplier would seem propitious. As each reminder becomes due, a standard message can be sent, tactfully asking the supplier to confirm that work on the order is going according to plan.

Inspection and Expediting Visits to Manufacturers

Some long-lead purchase items, especially including equipment, require more than the suppliers' assurances. In these cases the purchase contracts will make provision that give the purchaser or its agents authority to visit the supplier to inspect the goods during manufacture to verify that quality and progress are in order.

Large purchasing departments and overseas purchasing agents will have engineers on their staff who are technically qualified to inspect work in progress. These people are thus able to carry out the dual role of progress checking and inspection for conformance to the specification. For very important purchases with a long manufacturing cycle several such inspection and expediting visits may be necessary.

It is sensible and usual for the inspecting and expediting engineer to issue a report following each visit, both for information of the purchasing manager and the project manager. An inspection report pro forma is shown in Figure 20.3.

More Urgent Expediting Methods

The expeditor should react promptly and firmly whenever the reply to a routine expediting inquiry is unsatisfactory. The special efforts of the purchasing department should not stop until the supplier has either shown the necessary improvement or has actually delivered the goods.

Sometimes a new method of approach to the supplier can produce the desired result. An offer to arrange collection of the goods from the supplier's premises will, for instance, make the supplier aware that the purchaser is willing to participate constructively and that, on this occasion at least, there is genuine urgency.

Sometimes project managers become frustrated with purchasing departments and feel that they are not doing enough to expedite late orders. Perhaps the purchasing manager in those cases does not share the project manager's personal commitment to getting the project finished on time. One of us, when suffering such frustration, once sent a carefully composed letter to a supplier, explaining why a particular item was urgently wanted for a vital export order for which the quoted delivery time was 16 weeks. The item was delivered in only two weeks. That order was for just two small flexible drive shafts which had practically no profit value to the supplier and (because the shaft lengths were not standard) caused the supplier to interrupt a high-volume production run of automobile tachometer drives and make a special machine set up. Similar letters were sent to two other suppliers on that particular project, and they achieved almost the same degree of success in getting the parts on time.



Figure 20.3 An inspection and expediting report
A convenient format for summarizing the results of visits to equipment manufacturers.

Alternative Sourcing

When expediting appears to be failing, the design engineers might be able to suggest an alternative item that can be obtained more quickly. The solution might instead mean finding another source of supply. If the original order does have to be canceled because the supplier has failed to make the agreed

delivery, there should be no penalty for the purchaser, because the supplier has broken the contract by failing to fulfil the delivery conditions.

Commitment and Motivation

The purchasing department will not usually be directing all their attention to one project, unless it is very big. Quite understandably, each purchasing order which passes through their hands could be regarded by the expeditors as just another routine job.

Projects of sufficient size can justify the allocation of a buyer or even a group of buyers and expeditors to the project. These staff should be seconded to the project from the purchasing department if possible but they might have to be recruited specially as temporary staff or contract staff.

Special staffing should be particularly effective in a project team organization, because the reporting line is to the project manager rather than to the materials or purchasing manager. The buyer and expeditor (they might be the same person) become part of the team and should identify themselves more closely with the success or failure of the project.

Project managers should be motivated by a sense of personal involvement with the success of their projects and realize that their own career prospects can be closely linked to the project success or failure. This realization should spur the project manager on to exercise initiative, perseverance, tact and (in the last resort) guile. For these reasons the project manager can sometimes be successful in preventing or clearing a shortage which has been accepted by others as inevitable. The effective project manager refuses to accept defeat and explores every avenue until a solution is found.

Intervention by the Project Manager

If the supplier definitely cannot deliver on time, the project manager must be brought into the picture. To decide just how important the delay is likely to be and authorize emergency measures if these appear to be justified. In the last resort the project manager must feel free to intervene in the expediting process, even if this brings accusations of interference from the purchasing manager. The example given above about the success achieved by writing special letters was a clear case where the purchasing department's routine

procedures had failed to improve the suppliers' promises, and the project manager refused to accept defeat and wrote letters to the suppliers himself.

SHORTAGES

Jobs are sometimes delayed because of materials shortages or have to be started before all the necessary materials have been assembled. This usually happens because, in spite of expediting, a supplier has failed to deliver on time. Shortages, however, can arise through many causes. These include breakages, theft, failure to notice low stock levels, incorrect specifications, purchasing mistakes, design mistakes, design changes and a variety of other reasons.

No project manager likes to see any job delayed because of shortages, and no one wants to start a task before being assured that all the materials are available to carry it through to the finish. Shortages do, however, occur in projects. Shortage lists are one way for bringing them to the purchasing manager's attention for action. Shortage lists can be used on any kind of project.

Shortage Lists

A shortage list is a communication from the project manager (or more junior manager) to the purchasing department conveying a request for urgent action to make rectify one or more materials shortages. A shortage list must:

- be quick and easy for the manager or supervisor of the affected task to use;
- state the degree of urgency;
- describe the missing materials by type and quantity;
- give precise information to the purchasing department so that the purchase order can be identified quickly and the supplier contacted;
- allow feedback, so that the project manager or supervisor involved can be told when to expect delivery.

The procedure should provide that the buyer reports back to the originator on what is being done to clear the shortages.

RECEIPT OF PURCHASED GOODS AND EQUIPMENT

Receipt of the goods is not the end of the purchasing story. The consignment must be examined at the project site or factory receiving bay to check for possible lost items or damage caused in transit. There might also have been some mistake by the supplier, either in the quantity supplied or in the nature of the goods. Goods inwards inspectors may wish to examine the goods more thoroughly to ensure that they comply with the purchase specification although, in recent years, the tendency has been to place more reliance on the suppliers' own quality procedures.

If the goods are accepted, the goods inwards personnel will record the consignment, usually by preparing and distributing a goods inwards certificate or by copying the supplier's own dispatch note (to act as a certificate). At least one copy of the certificate will go to the accounts department, who need it before they can pay the supplier's invoice. Another copy will go to the buying department, to cut short any further expediting action and close off the file on that particular order.

If the consignment is not received in satisfactory condition for any reason, it will be sent smartly back whence it came accompanied by a rejection note. Distribution of rejection notes generally follows that of acceptance certificates, but will produce opposite reactions from the various recipients. For example, the accounts department will not pay any associated invoice, and the purchasing department will redouble its expediting efforts.

When the correct goods have been received they will be passed into stores or placed with project stocks to await use.

PURCHASE ORDER AMENDMENTS

Should it become necessary to change any aspect of a purchase order after issue, the supplier's earliest agreement should be sought to determine the effect on price and delivery, and to ensure that the proposed change is within the supplier's capability. Once these facts have been successfully established, an amendment to the original purchase order must be issued.

Each purchase order amendment should bear the same reference number as the original purchase order, suffixed by an identifying amendment number (amendment 1, 2, 3 and so on). Purchase order amendments should be prepared on a standard format and be authorized in the same way as purchase

orders. Amendments must be distributed so that they are received by all recipients of the original purchase order or its copies.

Amendment or New Order?

The amendment procedure is often used to add one or more items to an existing order. But if the introduction of a new item would jeopardize the previously-agreed delivery date of any other item on the purchase order, clearly the best policy is to issue a fresh order for the new item, so leaving the supplier to carry on unhindered and with no excuse for failing to meet the original commitments.

The practice of adding a succession of new items to an existing order can result in a number of partial deliveries, none of which completes the order, so that administration becomes messy. The need to wade through a purchase order plus a pile of amendments to discover its total extent and the balance of deliveries and payments outstanding is time consuming and irritating. Invoice control is likely to be made difficult and payment disputes can result. Separate orders prevent these difficulties.

STORES ADMINISTRATION

Most problems arising out of the physical storage of goods can be resolved into a few well-defined categories:

1. Accommodation: requirements for floor space, racking and shelving, stockyards, and so on.
2. Labeling: marking the goods so that they can be identified later without ambiguity.
3. Location: recording the place where the goods have been stored so that they can be found when they are needed.
4. Preservation: paying attention to possible deterioration, limited shelf-life, cross-contamination between different materials and the storage environment generally.
5. Handling methods and equipment.
6. Health and safety (particularly associated with handling methods and hazardous materials).

7. Security: prevention of theft, wilful damage or misallocation.
8. Records and information systems.

This is not the place to describe standard, commonly used procedures for the storage of materials but we do need to stress one aspect that is important to many aviation projects. We refer to the pre-allocation of stored materials for projects (or otherwise the provision of bonded stores).

Physical Pre-allocation of Materials

In many projects some of the required materials and equipment might be available as stock items in the existing stores. Provided that these have been purchased and inspected according to procedures that satisfy the relevant regulatory authorities (where safety and reliability are concerned) these items can be pre-allocated for eventual use on the project. One way of doing this is to mark up the stores records or the actual storage shelves and bins to identify the pre-allocated items. However, the only safe method for pre-allocating materials for use on forthcoming project work is to withdraw them from general stock and place them in a separate project store. If this is not done it is certain that, pre-allocation or not, some of the stock will be used on other work, and so will be unavailable for the project when needed. Cheery assurances from the storekeeper that the deficient items are ‘on order’ or ‘expected any day now’ will not be well received. A project cannot be completed with empty promises.

Security

Safe custody and security of stock demand that the storage area can be locked up outside normal working hours. At other times stores entry will usually be restricted to authorized stores personnel. Regulations such as these are designed not only to prevent theft, but also to minimize the possibility of irregular or unrecorded withdrawals. Airport construction site stores are particularly vulnerable and need special protection, which can include a full-time watchman, dogs, patrols, high fencing, alarms, closed circuit television, security lighting and so on.

In manufacturing plants where aviation projects are carried out it is often necessary to place all the goods for a particular project in a bonded store.

This is a storage area with restricted access. Goods accepted into the store must be certified to be of a quality that satisfies the relevant regulatory authority and each consignment of materials must be identified by labels that show the source of supply (manufacturer) and the batch of manufacture. These provisions are made for two reasons:

1. To ensure that only materials and equipment of the specified quality are used on the aviation project so that safety and reliability will not be compromised.
2. To provide for traceability should any of the materials or equipment items fail in service. If there is a malfunction of any equipment upon which human life and safety depends, there must be a path traceable back to the source of those materials. When the batch containing a faulty item has been identified, other procedures in manufacturing and assembly must be in place so that all aircraft or vital ground installations on which items from that suspect batch have been used can be identified. Change procedures (Chapter 23) and build schedules (Chapter 27) are both relevant to traceability.

21
Managing Project Start-up

Once authorization has been received, the project ceases to be merely an object for planning, forecasting and speculation but becomes instead a live entity and a commitment for the organization responsible. Authorization procedures were outlined in Chapter 7, but now we are much farther on in the project life cycle, with the detailed planning already in place and with actual work and serious expenditure just about to begin. For the purposes of achieving all the project objectives, whether technical, budgetary or timescale, the appropriate project organization has to be set up, staffed and activated. All participants must be made fully aware of the particular roles they will be expected to play.

A project that does not start on time cannot be expected to finish on time. Long delays can be caused by prevarication, legal or planning difficulties, shortage of information or a lack of funds. Some high-profile aviation or aerospace defense projects can be seriously delayed through demonstrations or the actions of political groups or the pressure of public opinion. For example, the project to construct a third runway at London Heathrow (which, apart from general environmental issues involves the demolition of an entire village community) could not be expected to begin without any hitch simply at the stroke of an authorizing pen. Clearly many project start-up issues are outside the control of the project manager, who can only wait in frustration whilst the responsible agencies attempt to deal with the difficulties. This chapter picks up the action at the point in the project life cycle when these external difficulties have been settled and the project manager is given the green light to get on with the job.

PRELIMINARY ORGANIZATION OF THE PROJECT

Even when a clear technical specification has been prepared there are often many loose ends to be tied up before actual work can start. The extent and

nature of these preliminary activities naturally depend on the type and size of project.

Getting the Project Manager Started

One of the first tasks is to appoint the project manager. A desirable procedure in large projects with a high degree of complexity might be to seek out the person who spearheaded all the conceptual engineering studies during the proposal phase, and allow that person to take the actual project through to completion. In that way, what is eventually built or done should be what was actually intended. However, that is clearly not always practicable. Another way must be found to ensure that the project is handed over to the newly appointed project manager in such a way that there is no ambiguity about what has to be done, when, and at what cost.

Different companies have their own ways of dealing with this requirement. In some cases a project identification document (PID) can define the project sufficiently. Other companies follow a project charter and project contract route, where the charter is either the business plan or a document closely related to it, and the contract is a subsequent document that creates a binding internal contract between the company and its newly designated project manager (even though there might be a separate, commercial and legally binding contract made between the company and an external customer).

Whatever the procedure used, the important element is a project specification that tells the project manager exactly what is required. In other words, using the popular jargon, the project specification defines the project deliverables.

Charting the Organization

When the project manager has been named, an organization chart (organigram) should be drawn up and published to show all the key people and agencies concerned with the project. This chart must include senior members of all external groups who are to have any responsibility in the project. If the organization is large, the usual arrangement is to produce an overall summary chart and then draw a series of smaller charts that allow some of the groups to be shown in more detail. Depending, of course, on the

actual arrangements, an overall project organization chart might have to show:

1. key elements in the contractor's own organization, obviously including the project manager;
2. management teams working away from the contractor's head office (especially site teams on construction projects);
3. principal sub-contractors;
4. external purchasing agent (if employed) together with any outside groups responsible for expediting, equipment inspection and shipping arrangements;
5. independent consultants, acting either for the customer or the contractor;
6. representatives of government or local government departments (where relevant);
7. the relevant regulatory organizations.

Allocating Responsibilities: Deciding Who Does What

People must know what is expected of them. One tool that can assist the project manager to allocate responsibilities is the linear responsibility matrix, an example of which was shown in Figure 11.9. The job titles of key members of the organization are listed above the matrix columns and various important task types are listed along the rows. Symbols are placed at the appropriate matrix intersections to show primary and secondary responsibility for each of the task types listed.

Some writers make the error of declaring that all project tasks should be listed on a responsibility matrix. With possibly many thousands of tasks in a project, this is clearly asking too much, invites many wasted clerical hours and confuses the purpose of the responsibility matrix with the far more detailed work-to lists produced from computer scheduling. Instead, the responsibility matrix should be designed around task types or categories. For example, a matrix can show the person responsible for approving new designs in general, but it is not the place in which to list all the drawings that carry those designs (that function is performed by the drawings register or drawing schedule as described later in this chapter).

CORRESPONDENCE AND OTHER DOCUMENTS

The project manager will be well advised to take control procedures for project correspondence and document handling seriously. The organization could be placed in a difficult legal position if vital letters or other documents were subsequently lost. It is necessary to ensure that positive steps are taken to deal with the routing and control of documented information within the home office and with all external parts of the project organization.

Documents: Deciding Who Gets What

Most projects generate a great number of documents. Once all the planning, control and administrative procedures have been decided, all the associated forms, expected reports and other types of documents can be listed. It is then possible to consider each of these document types in turn and decide who needs to receive copies as a matter of routine. This should usually be on a 'need to know' rather than 'nice to have' basis (except that all requests for documents from the customer must obviously be looked upon favorably unless these would give away information that the contractor wishes to remain confidential).

If the documents are to be made available in electronic form, accessible over a network, it might be necessary to impose different levels of access for security purposes, thus preventing unauthorized people from seeing or interfering with sensitive or confidential data.

Once the regular distribution or availability of documents has been agreed, the decision can be shown and communicated on a chart arranged as a matrix. This is similar to the responsibility matrix that was shown in Figure 11.9. Each authorized recipient can be named and allocated a vertical column, and each category of documents can be allocated a horizontal row. A tick in the square at each grid intersection shows that access is permissible. Alternatively, a number written at the intersection shows how many hard copies of the relevant document each person should receive. Figure 21.1 illustrates the principle. For a large international aviation project the matrix would clearly have to be considerably bigger.

Internal Routing of Hard-copy Documents

There is always a risk that documents received safely by a company will be lost or misrouted within the project organization. There is a useful discipline which can be imposed to help prevent this problem, and to ensure that every document reaches the person who should take appropriate action. This procedure is based on the concept of two levels of distribution, *primary* and *secondary.* The following description explains how this can be implemented. The case described here is for incoming project documents, but copies of outgoing correspondence can be distributed in similar fashion.

Primary distribution of incoming documents Each original letter is date stamped on receipt and placed in central files. Sufficient copies are sent to the project manager, together with any enclosures from the original letter, to allow the project manager to arrange for secondary distribution. The number of copies needed would be specified in a written procedure (such as a project handbook or project manual).

Secondary distribution The project manager (or delegate) considers who should answer each incoming letter and take any necessary action. An action copy, with enclosures, is passed to the chosen individual. One copy is placed in project office files (the project support office, if such exists) and the project manager may decide to direct copies to other managers or staff for information.

The copy intended for action must be clearly indicated as such, to ensure that action is neither neglected nor duplicated by the recipient of a ‘for information only’ copy.

Document type: / Recipient:	The customer	General manager	Project manager	Project engineer	Works manager	Production control	Buyer	Quality manager	Accountant		and so on
Bought-out parts lists				1		1	2	1			
Material specifications				1			1	1			
Purchase requisitions				1			1*				
Purchase orders							1		1		
Shortage lists			1			1	1				
Committed cost reports		1	1	1			1		1		
Drawing list			1	1	1						
Drawings for approval	1			1*							
and so on.											

1 Number of copies per recipient

* Retains original signed document

Figure 21.1 Document distribution matrix

Nominated Addressees or Contacts

It is good practice for the organization at each separate location involved in the project to nominate one of its staff to act as a control point for receiving and sending all formal written communications and technical documents transmitted as hard copy. Each nominated addressee then becomes responsible for seeing that the documents or the information contained in them is made known to all relevant people within their own organization. Safeguards should be put in place to ensure that significant project documents transmitted direct to individuals by e-mail are copied into central project files to assist in subsequent information retrieval.

Document Transmission Methods

International projects, where the contracting organization is overseas from the customer, construction site or other project groups, demand careful attention to the transmission routes of documents that must be sent as hard copy. Specialist express postal services or international courier companies should be used for all urgent or otherwise important documents.

Good liaison between the company's travel department and the mailroom will ensure that travelers can be identified who might be persuaded to carry documents in their hand baggage, but this arrangement is often abused and individuals expecting to visit a project site or another company can find themselves weighed down with an alarming heap of excess baggage.

At some overseas destinations the customs authorities can delay release of documents, especially when these are sent as air-freighted cargo. The project manager should always use the professional advice of a reputable carrier or courier familiar with the required route. Local industrial disputes can cause complete hold-ups or frustrating delays. In other cases customs authorities have been known to be awkward for no apparent reason—in one case a large consignment of drawings intended for a project site was held at the destination airport while the customs authorities demanded payment of duty based not on the intrinsic value of the drawings but on the multi-million dollar value of the whole project. The solution in that case was to abandon the drawings (they might still be gathering dust in the customs shed) and send a duplicate set through another route. Of course many of these problems can be overcome by the electronic transmission of documents but some remote site offices may not have the high-volume, high-quality, large-size printers or plotters that are enjoyed by staff of the permanent home office, in which cases the site staff will not appreciate receiving massive electronic files from which they are expected to print all their working specifications and drawings.

Serial Numbering of Correspondence Documents

If a large amount of regular correspondence is expected, all the parties likely to correspond with each other can agree to use letter-reference serial numbers, prefixed with identifying codes. The following example illustrates how correspondence was numbered on one international project from our experience. All the names used here have been changed and no reference to any existing company is intended.

The project contractor was Verulam Aviation (VA) and its overseas customer for a very large project was Perfect Airways (PA). All document serial numbers were allocated in a straight sequence from 0001 up within each series.

	From VA to PA	*From PA to VA*
Letters	VAL 0001	PAL 0001
Faxes	VAF 0001	PAF 0001
Document transmittal letters	VAD 0001	PAD 0001

Apart from making consecutive filing and subsequent document retrieval easier, the use of a continuous series of numbers means that any gap in the sequence of numbers received at either end indicates a possible loss in transit that needs investigation.

The allocation of serial numbers requires some form of central register, to be administered by a suitable secretary or clerk (perhaps located in a project support office). Such formal procedures are really only suited to the dispatch of documents that have particular contractual or technical significance, or for bulk consignments of documents such as drawings and specifications. E-mail correspondence, where many individuals on a single project can communicate immediately with others worldwide from their desks, does not lend itself to such formality and it is up to the senders to ensure that their messages have been properly received and understood. However, some e-mails will have significance for the project historical records and we suggest that individuals should be asked to identify these and copy them to the relevant secretary or clerk. For reference purposes they could be allocated reference numbers in a sequence similar to that given above: in our example the series would be prefixed VAE and PAE.

Document Transmittal Letters

Consignments of drawings and other documents which are not accompanied by a serially numbered covering letter should be given consignment numbers, and this is best achieved by the use of standard ‘document transmittal letter’ forms. These are little more than packing lists, but each is given a serial number and copies are retained on file as a record of what was sent. In the case of the customs problem mentioned above where a large consignment of drawings was impounded pending payment of outrageous duty, the file copy

of the relevant document transmittal letter held by the sender listed all the drawing prints in the impounded consignment, enabling a duplicate set of prints to be made and sent.

Correspondence progressing Companies with a large volume of project correspondence arrange for a coordinator to ensure that every letter or other document that requires an answer is dealt with without undue delay. The same person will also follow up any possible losses in transit, apparent from gaps in the sequence of serial numbers received.

ENGINEERING STANDARDS AND PROCEDURES

Engineering Standards

The project manager will have to investigate whether or not the project calls for any special design standards, safety requirements, or compliance with government or other statutory regulations.

Compliance with standards is not simply an academic consideration, and non-compliance can have disastrous consequences on several levels (contractual, during manufacture or construction and when the project goes into service). Standards permeate all aspects of engineering design and manufacture and have to be taken very seriously, especially in aviation projects. Even the apparently innocuous question of drawing sizes once led to a terrible argument between one contractor and its long-standing customer, when the contractor suddenly began using A0-sized sheets without telling the customer, so that when thousands of completed drawings were delivered to the customer when the project was handed over, the customer was forced to re-equip its filing room.

Internationally recognized standards, such as ISO standards, play a great part in ensuring quality and compatibility between different companies (project contractors, suppliers and project operators). Military standards for many components also help in this respect. But even with all the published standards available, mistakes are still possible. The Airbus 380 development, which clearly relied heavily on compatible engineering standards across its many partners and sub-contractors, was reported to have suffered a serious setback when wiring looms manufactured by one partner

did not match the airframe connection points produced by another owing to incompatibility between the design software versions used by the different design groups. All readers will be familiar with difficulties in transferring digital files when the user and sender have different versions of the same program—for example later editions of some Microsoft Office products such as Word and Microsoft Project will not open files created in earlier versions.

All these questions must be discussed in detail with all participating companies in any aviation project and the solutions must be agreed at the beginning.

Drawing Numbers and Drawing Format

It is often agreed that the drawings made for a project carried out for an external customer or client are the property of that client or customer, who will expect to be provided with a complete set of duplicate drawings at the end of the project and file them in their own system. In such a case the contractor will probably have to discuss and agree the drawing numbering system to be used for the project. Common practice is to number each drawing twice, using the customer's system and the contractor's normal standard, and then cross-reference these in the computer or drawings register. Drawings may have to be laid out to the customer's own standard drawing format or drawing sheets, in which case the contractor must obtain supplies (or a digital template) before drawing can start.

Choice of Project Planning and Control Procedures

Companies accustomed to carrying out large projects may have at their disposal a considerable range of planning and control procedures. At the start of each new project these can be reviewed to determine which are appropriate for the particular project. Factors affecting this choice are the size and complexity of the project, the degree of difficulty and risk expected in meeting the end objectives, the number and locations of outside organizations and, last but never least, the wishes or directions of the customer.

Project Manual or Procedures Manual

For some projects contractors will compile a project manual (otherwise known as a procedures manual or project handbook). This will specify the particular procedures that will apply to the project. Listed below are just some of the items that a typical project manual might include:

- names and addresses of key organizations taking part in the project, not forgetting the customer;
- the names of key personnel in those organizations, particularly highlighting those who are the specific points of contact for various project matters;
- organization charts;
- drawing numbering system;
- project planning and scheduling system to be used;
- type and frequency of project cost and progress reports to be produced;
- linear responsibility matrix;
- document distribution matrix;
- incoming and outgoing correspondence prefix codes, if used.

PHYSICAL PREPARATIONS AND ORGANIZATION

Physical preparations must be made for any project that requires accommodation, plant, equipment, services such as gas, electric power, compressed air, water and so on. There is no typical case, because the requirements of every project depend very much on the nature of the project and the practices of its contractor. At one end of the scale is the project which will simply follow another in a manufacturing plant or assembly hangar, using the same staff, management and facilities. At the opposite extreme is the international project involving several large companies and an airport construction site in a foreign country where the infrastructure is unknown and likely to be lacking in one or more respects. In the latter case, making physical preparation for the main project is, in itself, a collection of very large sub-projects.

Start-up Checklists

All project managers will know the frustration caused during the initial days and weeks when, keen to start and with deadlines to meet, work cannot start because there is no information, no staff and a general lack of other facilities.

Lack of information is often the worst of these problems: not necessarily about the main objectives and features of the intended project but more likely about a hundred and one annoying details which have to be resolved before work can start.

The value of checklists is mentioned in several places in this book, and no apology is needed or made for giving additional space to this subject here. Standard checklists, applicable to all projects, present and future, can be used as questionnaires to preempt information requirements. The best checklists are developed and refined through experience, so that lessons learned on each project are remembered and put to use on projects that follow.

Here we should mention the analogy with cockpit checklists. Every flight can be regarded as a new project. Pre-flight checklists that have been developed through considerable experience help to ensure that each new flight 'project' will proceed safely from takeoff to landing exactly as intended.

Airport construction site checklist example An example where a checklist is very useful is when an airport construction site organization has to be established, particularly when this is to be overseas. Even for an experienced organization, that is clearly an enormous operation. All sorts of questions have to be asked, and answered. Some questions should already have been answered when the proposal was researched and the project was initially defined (see Figure 3.2, for example). When the project becomes real, the questions and answers have a more definite and detailed aspect, as shown in the checklist fragment in Figure 21.2. It is important to get answers as completely and as early as possible. The better the checklist, the earlier and more completely these answers are likely to be obtained.

Workplace checklist for a Lox Aviation project to inspect and recondition landing gear The list shown in Figure 21.3 is the initial issue of a checklist designed to ensure that safe and efficient working conditions can be provided in work areas that are being prepared in readiness for a project to inspect and recondition an aircraft landing gear. In practice this list would need

further consideration and development, but we have shown the principles. If the workplace conditions are safe and ideal, the turnaround time for each aircraft will be reduced and there will be less risk of poor-quality work or an on-the-job error or accident.

Standard start-up checklists in the form of a network diagram One company in our experience designed a checklist in the form of a network diagram, a copy of which was used at the start of each new project. Figure 21.4 is based on that example. Time estimates and time analysis were never used on this standard network. It was used only as a checklist, but its value lay in the fact that it listed all likely preliminary activities in their logical sequence.

How many people will be working at the airport site?
How many of these people will be:
- our own permanent staff?
- our own fixed-term contract staff, hired for this project only?
- local recruits? (will they need training?)
- client's staff?
- sub-contractors' staff?

What accommodation must be provided?
- how much?
- what standard?
- who will provide it?
- rent free?

What are the local immigration rules?
- passports and visas?
- work permits?
- any racial prejudices?

Local employment laws and practices?
What about expatriates' wives and families?
Standard terms of employment?
Pay and personal taxation?
Insurances:
- staff related?
- work related?

Staff medical, welfare and leisure facilities?
Climate?
Site access:
- road?
- rail?
- air?
- other?

Vehicle fleet:
- personnel carriers?
- goods and heavy materials?
- how provided?
- how managed and maintained?

Construction plant:
- what is needed?
- when?
- how provided?
- how maintained?

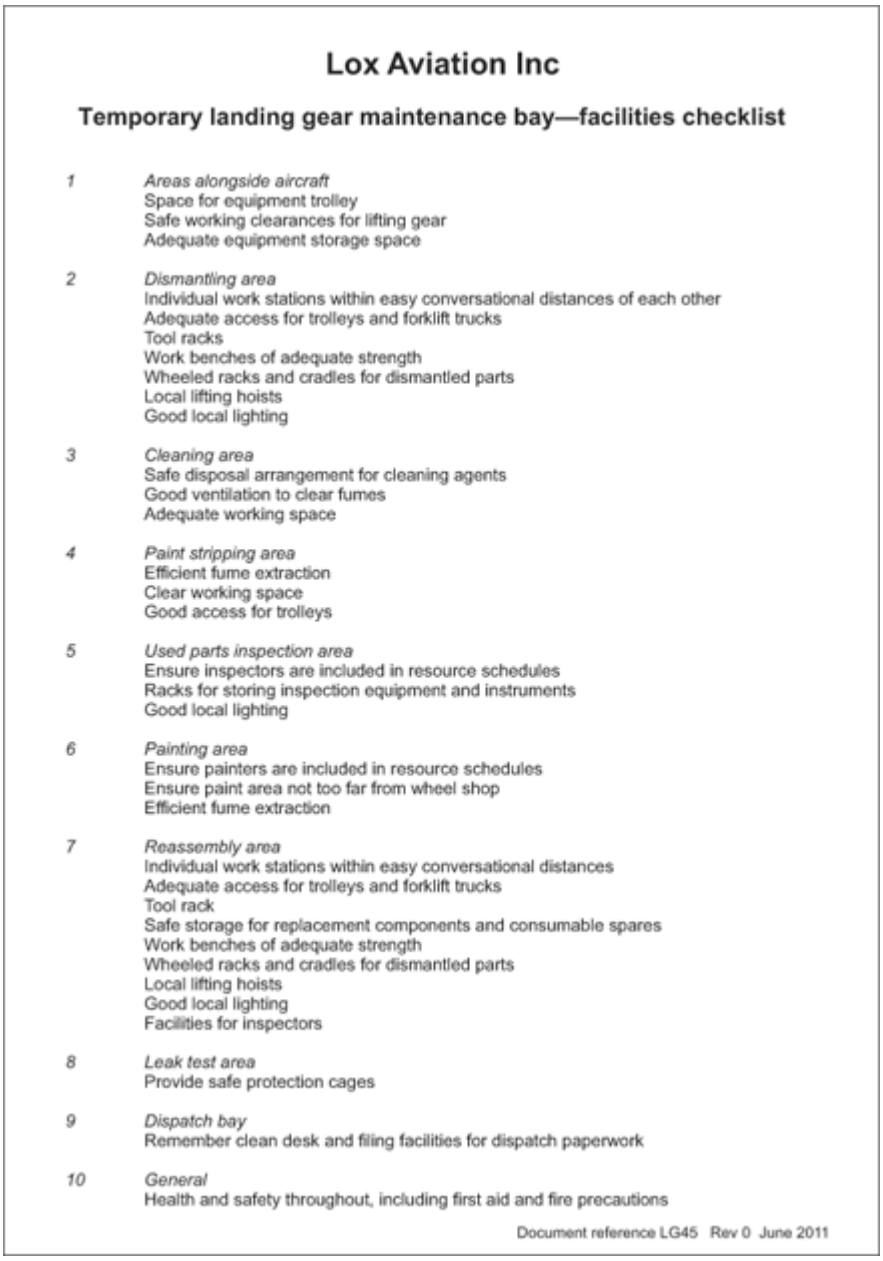
Figure 21.2 Fragment of a site checklist for an overseas airport construction project that employs interacting contractors

GETTING WORK STARTED

We can think of several key words that personify the start up of a successful project. Chief among these are:

1. Information (knowing exactly what is wanted).

2. Motivation (the determination to get things done).
3. Communication (communicating the information and motivation to all members of the project).



Lox Aviation Inc

Temporary landing gear maintenance bay—facilities checklist

1 *Areas alongside aircraft*
Space for equipment trolley
Safe working clearances for lifting gear
Adequate equipment storage space

2 *Dismantling area*
Individual work stations within easy conversational distances of each other
Adequate access for trolleys and forklift trucks
Tool racks
Work benches of adequate strength
Wheeled racks and cradles for dismantled parts
Local lifting hoists
Good local lighting

3 *Cleaning area*
Safe disposal arrangement for cleaning agents
Good ventilation to clear fumes
Adequate working space

4 *Paint stripping area*
Efficient fume extraction
Clear working space
Good access for trolleys

5 *Used parts inspection area*
Ensure inspectors are included in resource schedules
Racks for storing inspection equipment and instruments
Good local lighting

6 *Painting area*
Ensure painters are included in resource schedules
Ensure paint area not too far from wheel shop
Efficient fume extraction

7 *Reassembly area*
Individual work stations within easy conversational distances
Adequate access for trolleys and forklift trucks
Tool rack
Safe storage for replacement components and consumable spares
Work benches of adequate strength
Wheeled racks and cradles for dismantled parts
Local lifting hoists
Good local lighting
Facilities for inspectors

8 *Leak test area*
Provide safe protection cages

9 *Dispatch bay*
Remember clean desk and filing facilities for dispatch paperwork

10 *General*
Health and safety throughout, including first aid and fire precautions

Document reference LG45 Rev 0 June 2011

Figure 21.3 Workplace creation checklist for a landing gear inspection and reconditioning project

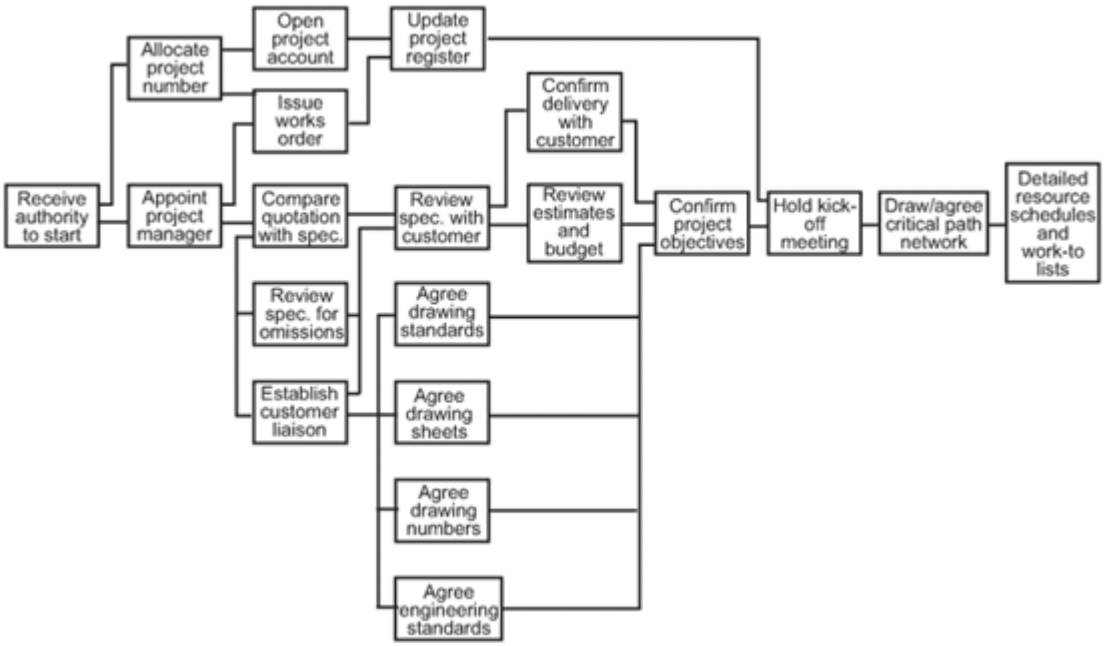


Figure 21.4 A standard project start-up network and checklist

Previous chapters have dealt with aspects of obtaining information in terms of defining the project and planning its tasks. Organization, also described in previous chapters, has much to do with allowing effective communication. So now we come to motivation. There are many factors that can motivate people to perform their jobs well, and these have been studied by the management behavioral theorists for well over a century. Right now we have a project to start and the project manager should be anxious to get people fired up and ready to start work.

The Kickoff Meeting

The most urgent job of the newly appointed project manager is to mobilize all the project resources and tell the key participants what is expected of them.

This process takes place in different stages and by a variety of methods. The first executive action of the project manager is usually to call an initial meeting, often called the ‘kickoff’ meeting, which gives the project manager the opportunity to outline the main features of the project to managers whose departments will work on the project, and to the most senior design staff and other key people. If the project is organized as a team, the project manager will have the advantage of talking to direct subordinates. If the organization

is a matrix, the task is more difficult—even getting people to attend the meeting becomes a question more of invitation and persuasion rather than issuing a direct summons.

It is desirable to have at least one representative of top management present at the beginning of the kickoff meeting to introduce the project and its manager to everyone present. That should help to assure everyone that top management are interested in the project and its outcome, and will be willing to give their unequivocal support to the project manager and the chosen project management methods. Then the project manager must make the best possible use of the initial meeting to get the project off to a good start. Everyone who attends the meeting should leave with a clear picture of the project's objectives, the part that they are expected to play in achieving them, and a sense of keenness and motivation to get on with the job.

ISSUING DETAILED PLANNING AND WORK INSTRUCTIONS

Plans and schedules will do no good at all if they are merely framed, hung on a wall and regarded thereafter as objects to be gazed at and admired. The project manager must make certain that the contents of these schedules are made known to every key person in the organization, preferably using specifically targeted work-to lists.

Importance of Personal Agreement and Commitment

Enough has already been written in earlier chapters about the methods available for producing plans and working schedules. If the project is of any significance at all in terms of its size, complexity or perceived importance, it must be taken for granted that detailed planning will be performed, and that this will involve input from at least one senior representative from every key project function. This involvement might mean full attendance at an intensive network brainstorming session, or it could mean instead asking these key representatives to view, review and approve a network produced automatically from templates or other standard library data (Lock, 2007).

Each key participant must, therefore, have some share in formulating and agreeing the detailed plan. This is just as it should be, because no plan can

be imposed successfully in isolation. It must carry the acceptance and support of those who are to be bound by it.

As soon as detailed planning has been carried out, the computer can be instructed to analyze the network, carry out resource allocation (if required) and produce a work-to list for every project department.

Issuing Work Schedules: Targeting Action Instructions

Dissemination of programmed information must be made far more effective than the simple blanket distribution of common schedules to all and sundry. Instead each department should receive a work-to list showing only those tasks for which it is responsible. Instructions are often ignored when they are issued to too many people instead of only to the person who is expected to arrange for action. If an instruction is issued in a document that goes to more than one department, each may do nothing and rely instead on the other to carry the instruction out. There is also a slighter risk that some tasks might be performed twice. Such risks exist when project networks or other schedules are distributed to a wide number of departments or people without any explanation or precise instructions for action. Properly filtered work-to lists, on the other hand, possess the advantage of being specific to their addressees, so that management responsibility for each item on each list is the clear responsibility of the recipient.

Work-to lists usually need to be provided in detail to cover only a few weeks ahead, but longer-term summaries may have to be given to help departmental managers to recruit or reserve the necessary people. All of this is readily achievable with the filtering and sorting capabilities of project management software, and it is now that the benefits of the coded WBS and OBS described in Chapters 10 and 11 will begin to be realized.

Recognizing the Authority of Departmental Managers

The instructions or reminders contained in work-to lists should in no way detract from the personal authority vested in each departmental manager. Although the source of each instruction is the project manager's office or the project support office, the information should derive from the detailed project plan that was first made, reviewed and agreed with the departmental

managers themselves. The authority of these managers, far from being undermined, should actually be reinforced.

Managers receive a list of the work required of their departments, together with information about when the work should be performed, but they are otherwise free to allocate tasks to individuals within their departments and to direct and control those tasks. With work-to lists resulting from sensible resource scheduling, there should be no chronic departmental overloads (temporary overloads will always remain a risk). The departmental managers are thus provided with very effective tools that should help them to control the project activities within their particular groups but which in no way diminish their line authority.

Work-to Lists for the Manufacturing Plant

Work-to lists for manufacturing will usually be sent to the production manager or production controller, who will issue internal works orders, job tickets, route cards or any other form of document demanded by the customary procedures used throughout the manufacturing organization.

The levels of detail shown in project networks (and, therefore, in the resulting work-to lists) are bound to be far coarser than those needed for the day-to-day (even minute-to-minute) planning and control of plant operations. Work-to lists should, for example, provide the expected start and required finish dates for each assembly and sub-assembly. It is highly unlikely that any work-to list derived from the project schedule will specify a greater degree of breakdown. It will not include all the smallest components or parts needed for the project.

Thus the manufacturing organization will use its own production engineering, planning and control facilities to interpret drawings, write instructions for numerically controlled machines, identify the parts and materials required and carry out detailed production scheduling. This must be done to satisfy the dates given on the work-to lists issued from the project manager's office but, provided that project resource scheduling was carried out effectively, the overall rate of working implied by the work-to list should lie within the capacity of the manufacturing plant.

Engineering Design

In engineering design departments, the work-to lists are more likely to be used for controlling day-to-day work without need for the multitude of additional documents and procedures that are always required in manufacturing departments.

However, networks are not always drawn with sufficient breakdown detail for the day-to-day allocation of work, and it might be necessary for design managers and supervisors to arrange for some more detailed local scheduling. For example, purchase and drawing schedules are usually needed to show a greater level of detail than is feasible on the project network diagram. A single network activity usually summarizes a group of drawings needed for a small work package or sub-assembly, and it is not usually desirable or possible to have a separate network activity for every individual project drawing.

Thus, in the same way that production department managers will be expected to regard the project work-to lists as a framework for their more detailed day-to-day jobs, so design managers must be expected to identify the daily chores and allocate jobs to individuals. They can, however, do this in the knowledge that the work-to lists feed work to their departments at a rate that should not cause overloads.

In most engineering design offices and other software groups, highly qualified staff can be found whose creative talents are beyond question. But, while their technical or scientific approach to project tasks might be well motivated and capable of producing excellent results, there is always a danger that these creative souls will not fully appreciate the importance of keeping within time and cost limits. The inclusion of estimated costs and target completion dates on work-to lists can help to make these specialists become more aware of their commercial responsibilities.

Purchase and Drawing Schedules

Purchase schedules (sometimes called purchase control schedules or other names) list all the important items that have to be bought in for a project. They usually list, for each significant purchase, the specification number, and subsequently the requisition and purchase order numbers. Once these had to be written manually in a very time-consuming chore, but now they will be set up and maintained in a computer file.

Drawing schedules (or drawing control schedules, or drawing lists) list all the drawings that will be needed for a project. They are very similar to a drawings register, and are indeed often used for the allocation of drawing serial numbers.

The central drawings register, where such exists, is a general company record but drawing schedules are specific to each project. Many companies incorporate the project number in their drawing numbers, and go further by numbering and arranging the schedules in sets that correspond with higher levels of the WBS coding. Apart from being of immense value to the project workers and all who come after, numbering to incorporate these WBS codes will ensure that there is no duplication with a central company drawings register. WBS coding systems were described and illustrated in Chapter 10.

Establishing the drawings schedule for a project is usually carried out as a complementary function to setting up the purchase schedules. It is an essential part of the project start-up activities and, once again, the clerical chore of creating and updating them is made much easier using a computer.

A project support office can be the home for creating and maintaining purchase and drawing schedules. However, grouping these documents in sets structured on the WBS or the OBS higher-level codes will enable the task of creating them to be distributed over all the specialist design groups involved without fear of introducing the risk of errors of omission or duplication.

When the project is finished, the drawing and purchase lists have to be updated to show all the final drawing numbers with their correct revisions, and all the purchase specification numbers and their final revisions. When complete, these schedules allow information retrieval and define the ‘as built’ condition of the project. They are similar to the build schedule documents that will be described in Chapter 27, the principal difference being that drawing and purchase schedules define a single project whereas build schedules are used for defining the content of manufactured products that are made in two or more different versions.

REFERENCES

Lock, D., (2007), *Project Management*, 9th edn, Aldershot, Gower, pp 480–90.

22
Managing Progress

This chapter is about helping to prevent project delays. It must begin with the assumption that an effective schedule has been produced, and that all key project participants know, and have agreed to, what is expected of them.

PROGRESS MANAGEMENT AS A CLOSED LOOP CONTROL SYSTEM

One prerequisite for any control system is a method for measuring the effect of any command given. The information so derived can then be fed back to the command source so that any errors can be corrected by modifying the original command. An artillery commander watches the fall of the initial shots and uses the results as feedback signals to the gunners, so that they can correct the aim of the guns. In electronic amplifiers, well-established design practice is to arrange for some of the output signal to be fed back to the amplifier's input in opposite (canceling) polarity. That process tends to correct any distortion of the signal created within the amplifying system.

Thus feedback signals are used to correct errors, whether these happen to be the aim of a cannon or distortion in an amplifier. If the feedback signal is disconnected, the system is said to operate as an open loop. When the feedback signals are applied to the input, the control loop is closed.

Effective project progress control is a form of closed loop feedback system. For every instruction issued, progress is monitored, deviations from plan (errors) are detected and corrective feedback is applied. The competent project manager (the project pilot, if you like) will ensure that these corrective actions do take place. This principle of *command—measure—feedback—correct* operates at the level of each individual task, at higher levels of the WBS and for the whole project. Because of the close electronic analogy this process has been called *cybernetic control.* The principle is shown in Figure 22.1.

In aviation, a similar analogy is seen when a pilot lowers the landing gear on approach. In this case the pilot must be considered to be within the control loop. The command to lower the landing gear sets in chain a series of electric and hydraulic tasks and, if all goes well, the landing gear lowers and is locked into place. Feedback signals to the cockpit confirm successful function. Should anything go wrong with this operation, the feedback loop will signal an alarm in the cockpit to tell the pilot that some sort of action is needed. If we stretch this analogy a little further, lowering the landing gear might be considered a mini project, with the pilot as project manager (Figure 22.2). Failure of the landing gear to lock down safely in position would clearly be a critical failure requiring urgent action from the pilot.

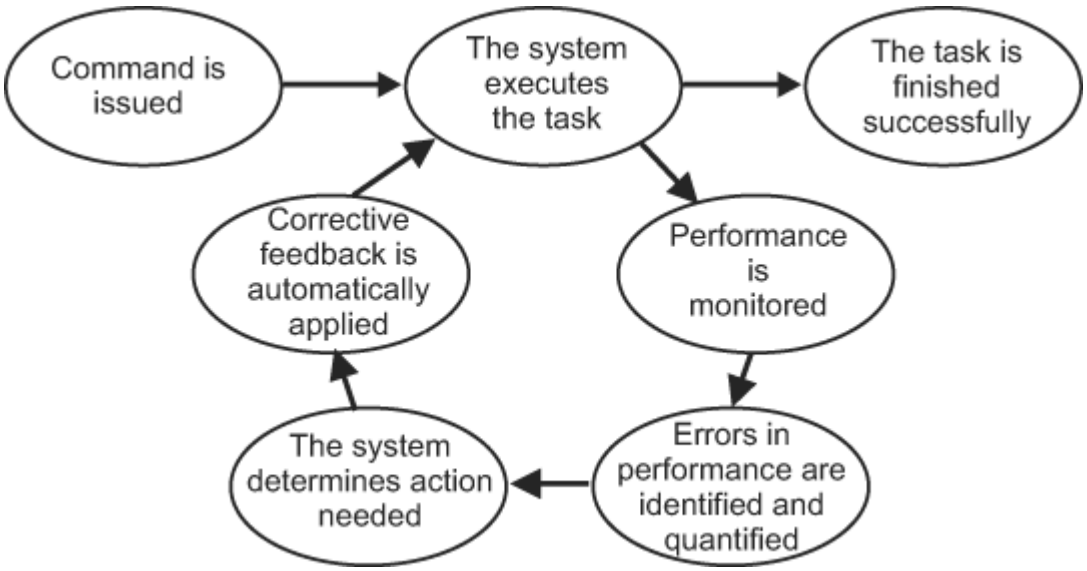

Command is issued
The system executes the task
The task is finished successfully
Corrective feedback is automatically applied
Performance is monitored
The system determines action needed
Errors in performance are identified and quantified

Figure 22.1 A cybernetic control loop

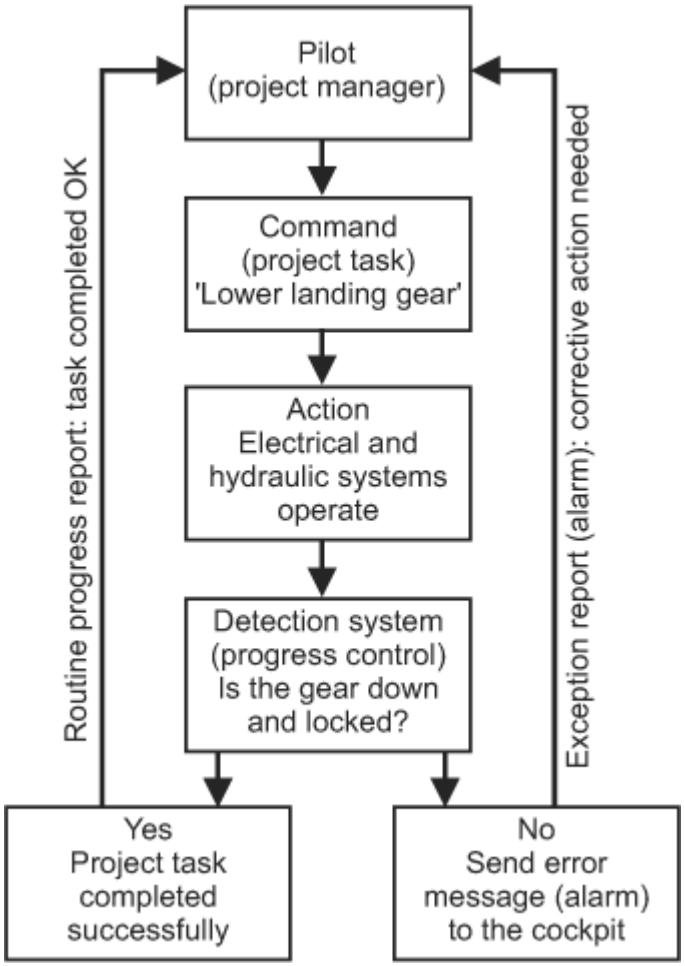


Figure 22.2 A project task instruction compared with an in-flight command

However, most malfunctions are relatively less critical and the only action needed from the crew is to note them in the log book as items needing attention from the ground maintenance staff. So it is with all projects. Some tasks need immediate action when they go wrong, but many others can be dealt with at greater leisure. Modern project managers have the advantage of project schedules based on critical path analysis, so that for every task the amount of remaining float available should be known. Tasks running seriously late that have no float (critical tasks) clearly demand instant action whereas more tolerance can be given to late tasks with substantial float. This does not mean that managers should become complacent when tasks begin to run late (because such problems have a nasty habit of accumulating) but it does allow managers to focus their progress control where it will be most effective.

PROGRESS MANAGEMENT STYLES

The development of management theory has one feature in common with the fashion industry, namely that this year's styles are next year's history. However, many management theories do survive and become valuable in helping us either to understand management better or to apply the principles in practice. Over the past 60 years or so a number of different people have identified management styles that all begin with the words 'management by'. Examples follow.

Management by Objectives

Management by objectives is a methodology based on setting each manager in an organization a set of quantifiable objectives, and then measuring how well or how badly each manager manages to achieve those objectives. Each objective must be quantifiable and measurable, and vague statements such as 'improve performance' are not acceptable.

At the most extreme level of implementation, the organization must first be analyzed and charted and then the role of every manager from the chief executive down to the lowliest supervisor is examined and specified in a job description. Then, quantified objectives are established at each level that, when considered collectively throughout the company, build to equal the objectives of the whole organization in a hierarchical pyramid. That concept is fine in theory and has much in common with the WBS for a project. However, the setting-up process takes so long (often years) that by the time all the job descriptions have been written and the objectives have been set the organization itself will have undergone fundamental change, thus wrecking the grand MbO design structure.

However, when practiced more informally, management by objectives has much to commend it. Managers set objectives for individual people in their departments themselves and review the results at three-monthly intervals, setting new objectives at each review. Each objective set must be quantifiable, so that when performance is assessed there is a yardstick against which it can be measured. Thus, for example, 'improve performance in design accuracy' would not be a measurable objective but 'reduce the average after-issue time on drawings from the current 30 per cent to 25 per cent' would be.

By now you might be asking 'What has all this to do with project management?' The answer is quite clear. Project management is nothing less, nothing more, than management by objectives. Quantifiable objectives are set when the project is defined, they are distributed over a WBS and OBS, and then managers strive to achieve the set objectives by a predetermined date. If all these objectives are delivered, then the project objectives will also have been satisfied.

Management by the Seat of the Pants

This style of management derives its name from riding a horse or flying a plane. It refers to control based on instinctive feelings of whether or not things are going in the right direction. Although there are a few individuals who possess this ability in project management, most of us do not. Therefore we must rely on more scientific or practical methods, such as those described throughout this book.

Management by Walking About

There was once an engineering director who sat in an office filled with beautiful antique furniture. He could only be approached through an outer office, also filled with beautiful antique furniture and a secretary (who was beautiful but not antique). Outside these two offices was a vast floor occupied by many functional design engineering managers, senior engineers and designers. The engineering director seldom emerged from his office, and only met his subordinates at infrequent meetings. The word went around the junior staff, as a joke with some substance, that the engineering director did not really exist, but was only an empty office and a secretary. That true story (from our own experience) is the antithesis of management by walking about.

A manager who does 'walk about' will visit parts of the project to see at first hand the progress that is being made and, most important of all, give motivating words of encouragement to everyone working on the project. If some of the activities are at other locations, the project manager should make occasional visits there too. People respond well if they know that they are appreciated. A small word of encouragement here and there costs little but the return on investment can be enormous.

Failure to perform this very simple function of walking about is a great demotivator. A project cannot be managed effectively by sitting all day behind a desk within a closed office.

Management by Surprise

Management by surprise has its origins in manufacturing, but it has universal application to any cybernetic control system where the loop is not closed. A manager puts work into the front end of a manufacturing plant or design office and is surprised when it fails to come out at the other end as expected.

Management by Exception

With any cybernetic control system it is the error signals that have greatest significance for control, because these are the means for generating corrective action. In the project management context, divergences from plans and budgets or any unexpected setbacks are called *exceptions*. Cost and management accountants call their exceptions *variances*. Exceptions and variances can apply to advantageous differences from plan but, for control purposes, it is the negative exceptions and potential failures that must demand attention.

Management by exception means concentrating management efforts on the bad variances or exceptions. If something is running early and five per cent below its budget, that's fine, leave it alone, don't tell me about it. But if another job is running late or five per cent over budget, concentrate on that and put it right.

Exception reporting Exception reports are a product of management by exception. They might be accounts statements that show overspending or they could be lists of jobs that are running late. At the other extreme, an exception report might be the frenzied beating on a senior manager's door by a distraught project manager who feels that the project and everything to do with it have suddenly fallen apart. A perfect personification of an exception report is the materials shortage list (Figure 22.3). Such lists are often used as a cry for help from the manufacturing plant or assembly hangar to the purchasing agent whenever progress is at risk from lack of supplies.

Before allowing any exception report to be passed up the organizational hierarchy to a more senior manager for action, project managers must first be certain that some remedy within their own control cannot be found. However, once it has been established that events are likely to move out of control, the project manager has a clear duty to give senior management the facts without delay. All of this is, of course, following the management by exception principle that prevents senior managers being bombarded with large volumes of information that should be of concern only to junior managers and supervisors. The intention is to leave executive minds free to concentrate their efforts on higher corporate strategy, to the best advantage of the company.

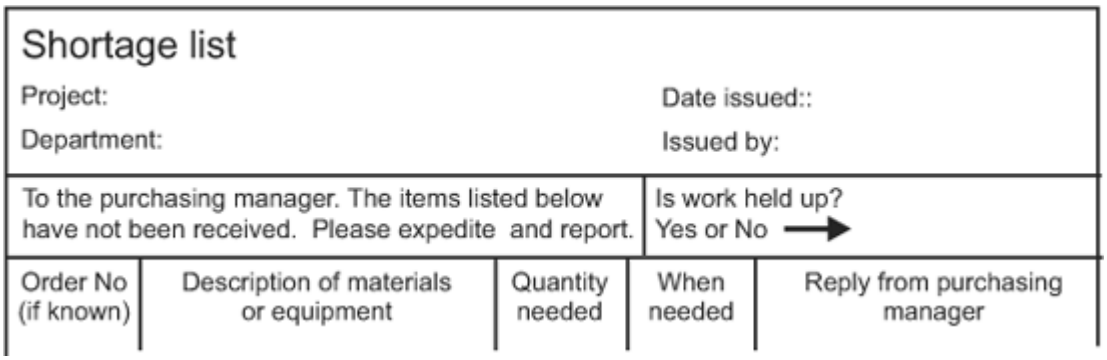

Shortage list
Project:
Date issued::
Department:
Issued by:
To the purchasing manager. The items listed below have not been received. Please expedite and report.
Is work held up? Yes or No
Order No (if known)
Description of materials or equipment
Quantity needed
When needed
Reply from purchasing manager

Figure 22.3 Materials shortage list format—a perfect example of management by exception

UPDATING DRAWING AND PURCHASE SCHEDULES AND RECORDS

Drawing and purchase schedules (they might be called drawing and purchase lists in some companies) contain much information that is liable to change as the project proceeds. Therefore they must be kept up to date. When everyone working on a live project has access to schedules over a computer network, the problems of issue and correct revision status are partly avoided. If, on the other hand, schedules are to be distributed as hard copy, they must be re-issued at regular intervals and subjected to rigid version control (by specifying the relevant revision number).

When the project is finished the purchase schedules, because they list all the purchase specifications and other purchase details, become part of the essential documentation that records the ‘as-built’ state of the project.

Similarly, the drawing schedules list all the drawings used on the project, together with their final revision status.

In construction projects there is always a theoretical ‘as-built’ project condition that should be capable of precise definition. When an airport has been built and put into service, every aspect of that airport should be defined somewhere on a drawing or specification. Of course many changes will occur subsequently as a result of normal operations and maintenance, but still it should be possible theoretically to finish the project with documents that define the as-built condition of the airport on the day when it is handed over to the owner for starting up all the services.

In manufacturing projects, such as aircraft manufacture, as-built definition is far more complex. It is indeed possible that no two aircraft will leave the assembly hangar exactly alike as a result of manufacturing concessions, design modifications and other changes, customization for different buyers and so on. Then as-built definition has to be applied to each individual aircraft. The process for achieving that level of definition depends on the compilation of build schedules, a process that is described in Chapter 27.

UPDATING THE PROJECT NETWORK DIAGRAM AND WORK SCHEDULES

Updating is the process of producing a fresh set of works schedules and other reports to take account of one or more of the following:

1. Any change to the project parameters, such as an unexpected increase or decrease in the numbers of resources available, changed cost rates, a newly imposed target date or a change to the project scope or specification.
2. A change in the network logic. This could arise, for example, as a result of a serious technical problem and consequent change of design strategy. Sometimes jobs are performed out of their logical sequence. Strictly that is never possible if the network logic is to be taken seriously, but most network diagrams are less than perfect in this respect and allow more tolerance in practice than the logical constraints would suggest. When tasks are performed out of sequence, the network should be corrected so that all tasks remaining are correctly scheduled.

3. The need to produce schedules that take into account progress made to date.

Some people like to save a baseline model of the project before making any changes so that they have a permanent record on file of the project as it was originally planned and costed.

Updating frequency If a schedule has been produced that proves to be practicable in all respects, and if everything goes according to plan, there is strictly speaking no need at all to return to the computer for a new schedule during the life of the project. This could very well be the case for a simple project, or for a schedule covering only a very short total time span. Even a more complex project has been known to run entirely according to its original plan, where the plan was well made and the project particularly well managed.

In most projects, however, too many unknown factors lurk, waiting to give us unpleasant surprises. Just when things appear to be on plan, a key supplier fails to deliver vital materials, a design error is discovered that will take weeks to put right, the regulating authority says 'No! You can't do it that way' or the customer puts in a late modification. Airport construction sites have their own brand of hidden surprises, such as when a construction site supervisor was horrified to see the scaffolding and formwork for a road bridge over a stream gradually settle into the shape of a graceful bow under the weight of much newly poured and liberally reinforced concrete setting rapidly under a tropical sun.

The integrity of a project schedule must be protected at all times. If anything happens that renders a schedule obsolete it must be updated as soon as possible. If that is not done people will lose faith in the plans and disregard them. Updating frequency can be contemplated in the following two ways:

- on an occasional basis, which usually means updating only when a change to the project or its progress has made the existing schedule inconvenient to use or actually wrong;

or

• on a regular basis (which very often means monthly).

Regular updating may be needed if the project is very complex, with large volumes of progress data to be digested. For some projects, regularly updated schedules and their resulting reports provide an essential part of reporting to an external project client or customer. For internal projects they can be the core of reports to senior management.

For the day-to-day management of project work, it is clearly the current schedule that counts for issuing work and managing progress. Updated schedules simply follow later, to make certain that work yet to be done remains sensibly scheduled. If, for instance, only scrap is produced after six weeks of a manufacturing job, or if it is found that 100 yards of trench have been excavated along the wrong side of a runway, the manager does not need an updated schedule to signal that things are going wrong. Of course the manager takes immediate practical action to put things right, especially for critical tasks. The schedule must be updated, but that is a consequential process that follows once steps have been taken to sort out the immediate problem.

COLLECTING PROGRESS INFORMATION

Whatever the method used to gather progress information, care must be taken to avoid either ambiguity or undue complication. The simpler the method and the simpler the progress questions, the more likely are the chances of persuading all the managers involved to respond on time. Even so, persuading all key project participants to report progress regularly and on time often provides project managers with a real test of their mettle. Many attempts at project control fail because this progress feedback communication link cannot be established throughout all the lines of command. Matrix organizations are more difficult in this respect than pure project teams or task forces. The situation is particularly difficult in aviation projects that have one or more external partners working on parts of the project.

Using Task Lists or Work-to Lists as Progress Returns

We should all be agreed that active projects depend on two-way communication between the project manager and every participating manager. For every work instruction issued, information must be fed back on the resulting progress.

If the original commands are to be conveyed from the project manager to participants by way of work-to lists, why not use that procedure in reverse to feed back progress information? The only missing item is a document complementary to the work-to list for that purpose. This gap can be filled by one of the following methods:

- the use of specially designed progress return forms (on paper or on screen);
- line managers annotating and returning copies of their work-to-lists.

Some project management software packages allow space for comments on their work-to lists. The example in Figure 22.4 is redrawn from a report that one version of *Open Plan* includes in its standard range of reports. This example serves as a work-to list that can be annotated with progress information by all the departmental managers. Those managers will be expected to return their lists as progress reports to the project manager or project support office, who will replace them very shortly afterwards with fresh work-to lists.

For every active task on the current work-to list, the project manager (or project support office) will need to be told about progress in one of the following ways:

- the task has not been started as planned, for reasons given;
- the task has just been started;
- the task is in progress, with an assessment of the percentage of the task completed;
- the task is in progress, with the latest best estimate of the duration remaining to completion;
- the task is in progress, with the latest best estimate of the completion date;
- the task is completed.

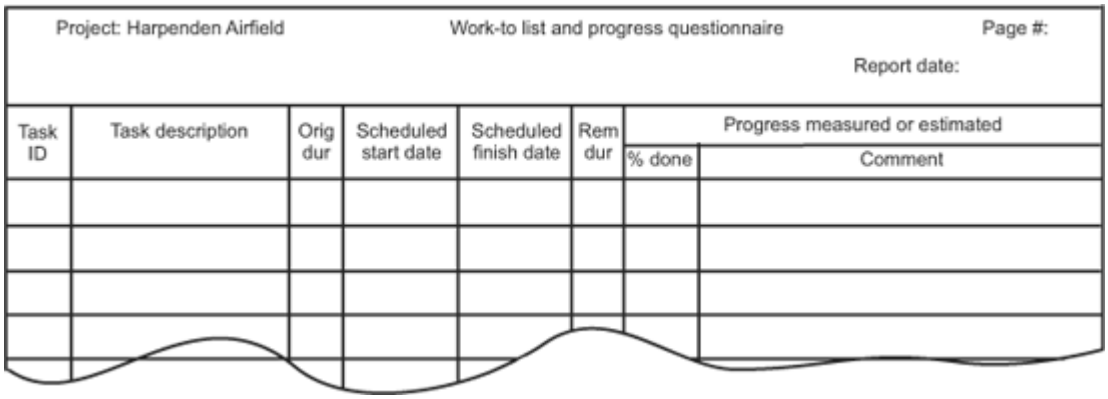


Figure 22.4 A combined work-to list and progress questionnaire

Time-now Date

All progress data should be collected with reference to the next 'time-now' date. 'Time-now' is, paradoxically, a date chosen in the future. It is the reference point from which time analysis and rescheduling will be calculated and from which the computer will reset all dates in work-to lists.

All people asked to provide progress information, whether directly from their keyboards or on paper, must be told the next time-now date. The planner will usually choose this time-now to be either the date on which rescheduling is to take place or a day or two later. Progress reporting against a time-now date therefore expects managers to forecast slightly ahead when assessing their results. With the rapid processing times of modern systems, it should not be necessary to place the time-now date more than a couple of days into the future.

If the schedules have to be updated frequently, as a result of numerous changes or for any other reason, reprocessing might have to be arranged at regular intervals. If the intervals are regular, the time-now rescheduling dates can be announced and annotated on calendars for many months ahead.

Frequency of Progress Data Collection

Progress feedback should be arranged at fairly frequent intervals, typically more often than the issue of revised work-to lists. Weekly intervals are suggested. If the intervals are too long, some problems might not come to light in sufficient time for corrective action to have any effect.

It is usually practicable for departmental managers and other senior staff to be given direct access to the computer schedules from their own keyboards. These managers can then report progress continually by this direct method. The project manager will want to be assured that progress information fed directly to the computer in this way, without first being subjected to checking and critical examination, emanates only from reliable and reasonably senior staff. False statements could lead to subsequent errors in network analysis, future resource allocation and work-to lists.

If the computer system is holding a large, complex multi-project model, the group or person responsible for scheduling will always be wary of any input that could corrupt the files and cause many hours of restoration work. So a project support office is a good place for gathering and checking progress information.

Questions of Logic

If the progress information is being gathered on forms, rather than by direct input to the computer, there is another question that the perceptive project manager needs to ask for each task that is reported as done. That question is: 'Can this task's immediate successor(s) be started now?'

This is the acid test of whether or not a task has truly been completed. If the network logic is correct, then a task cannot strictly be reported as complete if its immediately following dependent tasks cannot be started.

An alert project manager will recognize the danger behind a progress return which says that the percentage progress achieved is 100 per cent, but that the next scheduled task cannot start. This could mean that the progress claimed has not in fact been made. This anomaly also occurs when a design engineer has completed a batch of drawings, but refuses to release them for issue through lack of confidence in the design, or because they feel that (given more time) the drawings could be improved.

Sometimes an activity *can* be started even though one or more of its predecessors is not finished. For example, a design activity, although not complete, could be sufficiently advanced to allow the release of procurement lists for long-lead items. A network diagram cannot indicate all such possibilities and opportunities for speeding progress might easily be missed if the right questions are not asked when progress data are collected.

Activities are sometimes reported as started before one or more predecessors have been reported as finished. This is in contradiction to the logic enshrined in the network so that, when it happens, it indicates that the network constraints were not absolute. Nevertheless, if that is the situation, it has to be accepted and reported to the computer accordingly. The computer will probably report such activities as being started 'out of sequence'.

STATISTICAL CHECKS

One very useful occasional check is to ask how many people in a department, or staff of a particular grade are actually working on the project. The answer can then be compared with the manpower requirement scheduled for that date. Comparison of scheduled and actual cost curves can also be made, but the head count is quicker, more positive, and likely to produce the earlier warning of a potential problem.

Suppose that 35 design engineers are supposed to be working on scheduled activities on a given date. If only 18 people can be identified as working on the project, something is obviously very wrong somewhere. Although routine progress returns might indicate that everything is more or less on course, the head count shows that work on the project in the design department is not taking place at the required rate. Closer investigation might reveal that the project design is held up for lack of information, that work for another project has been given priority, or that the department is seriously understaffed. The project manager must take action to set the right number of people to work.

Now suppose that the project manager has carried out two checks which indicate that both the use of manpower and the rate of expenditure appear to be on target. There used to be (perhaps there still are) people who would gladly accept such results as indicating that all was well with their projects, mistakenly believing that if the scheduled number of people are actually found to be working on a project (or if the costs *recorded* to date are in line with the costs *planned* to date) then progress must also be on course. Of course, no sensible modern project manager would make such an assumption because it is necessary also to assess the value earned from the expenditure. This argument will be developed further in Chapter 26.

MANAGING THE PROGRESS AND QUALITY OF BOUGHT-IN MATERIALS AND EQUIPMENT

Suppliers' Procedures

A feature of project purchasing is that the buyer should take a detailed interest in the vendor's own project management and quality procedures. Several large companies and government departments insist that those who supply them with project equipment or carry out sub-contracts at least use critical path analysis, and they will probably be expected to show that their quality policy and procedures satisfy the requirements of the appropriate standards (such as the international ISO 9000 series). It is not unknown for purchasers in project organizations to offer advice to vendors in establishing their own internal systems.

Expediting

As far as the purchaser is concerned, the period following the issue of a purchase order will be one of waiting, and a great deal of reliance must be placed on the supplier. That is not to say that the purchaser can do nothing. This is the time when the expediters earn their money by keeping in touch with the supplier to investigate and spur progress. Expediting is not just a process of chasing up late deliveries. It requires communication (including possible visits) with the supplier during the waiting period. This either safeguards progress or provides an early warning system should the supplier experience any difficulty in meeting the order. However, the expediting process was described in Chapter 20 and we need not dwell upon it further here.

MANAGING SUB-CONTRACTORS AND AGENCY EMPLOYEES

Most companies use sub-contractors. They can be used in a variety of ways, the most common of which include the following:

1. To undertake tasks which require expertise or facilities that lie outside the main contractor's own capabilities (for example, heat treatment, plating

and anodising, gear cutting, chemical analysis, certification testing): this form of sub-contracting is typically handled and progressed through the contractor's standard purchasing procedures.
2. To provide additional 'temporary' staff to work in the contractor's own premises to cover work overloads or to substitute for permanent staff who are absent for any reason.
3. To undertake specified tasks externally, on the sub-contractor's own premises, where the main contractor's accommodation, plant or workforce would otherwise be overloaded.
4. To work on a construction site, carrying out the various trades or specialist services.

Temporary Staff Working on the Contractor's Own Premises

The supply of temporary staff for all kinds of duties has become accepted practice and many agencies exist, some specializing in particular trades or professional skills.

Some companies regard the employment of agency staff as a temporary expedient, to cover staff shortages caused by holidays, sickness or sudden work overloads. However, there are companies that plan always to keep a proportion of their total workforce as temporary staff, because that provides flexibility in the event of workload fluctuations and reduces the possibility of having to make permanent staff redundant when the project order book is less than full.

Planning for the availability of temporary staff Whenever agency staff have to be used, especially if the numbers are significant, the search for suitable agencies and ensuing negotiations should take place as early as possible so that manpower can be reserved at reasonable rates and with some guarantee of adequate performance. Project disasters excepted, the use of project resource scheduling techniques (such as those described in earlier chapters) should provide timely and sufficiently accurate forewarning. The project manager should ensure that the selected agencies are given enough time to mobilize or reserve their own resources. Care should be taken, however, to avoid long-term commitments and the payment of retaining fees —a request sometimes made by sub-contractors on the grounds that they

cannot otherwise guarantee to have people available when required. In our experience such retainers are unnecessary and we have never agreed to them.

Supervision From the project control point of view, although the use of short-term agency staff may be unavoidable, there are risks of errors and inefficiency in all cases where tasks require a good understanding of the company's procedures and working practices. In those cases some time and money must be dedicated to providing initial or induction training. Longer-term temporary staff can often settle into an organization and acquit themselves well, becoming indistinguishable from the permanent employees until the fateful day arrives when there is no more work for them.

All temporary employees working on the contractor's own premises should normally come under the day-to-day supervision of the company's own departmental managers and work should be issued, progressed and measured according to the same project management procedures that govern permanent staff. The only additional feature is to ensure that invoices received from the various agencies claim for the hours actually worked, and at the agreed rates. Verification of hours worked is achieved using weekly timesheets.

Agencies will generally expect their staff to fill in the agency's own brand of timesheets and these will be used as the input documents for the resulting agency invoices. However, for detailed and accurate recording of task times worked against appropriate project cost codes, contractors will probably require agency staff also to record their time using the contractor's own internal timesheet procedures.

Temporary Design Staff Working in Outside Offices

An extra dimension of risk is added when design tasks are entrusted to staff who cannot be accommodated within the contractor's own premises. In those cases, work allocation and day-to-day supervision is usually delegated to the sub-contractor's own managers. The main contractor will want to take steps to ensure that design quality does not suffer, and that the hours claimed by the sub-contractor equate to the hours actually worked. The outside offices may be situated at long distances from the main contractor's offices.

Sub-contract liaison engineer One way of overcoming these problems is to place a supervisor in the external office, which of course will require the agreement of the subcontractor. Another approach is to appoint one of the project company's permanent engineering staff as 'sub-contract liaison engineer'. The liaison engineer visits all the external offices at very frequent intervals to perform the following tasks:

- deliver new work;
- ensure that the project design standards are known and followed;
- monitor and report back progress;
- answer technical queries on the spot;
- collect completed work.

Revealing task priorities and budgets to external agencies Managers differ in their opinions regarding whether or not to give sub-contractors information on the amount of float available for a task, or the cost budget that has been set aside for the work.

We prefer to tell sub-contractors the amount of float available because that information conveys true priorities and is the main factor in deciding whether or not overtime working (and therefore overtime premium costs) are justified. The higher cost rates of overtime should usually be accepted for work on tasks that have little remaining float, are critical or are already running late.

Other companies will have different views. Some will argue that the only schedule information needed by the sub-contractor is the scheduled start and finish date of each task, regardless of float.

If in doubt, a compromise can be suggested. Sub-contractors should be told if any job has zero or negative float. For all other jobs, the sub-contractor might be allowed to infer that float exists, but they will not be told how much—only that the work is expected to start and finish on the dates scheduled.

Budget data have to be treated differently. We take the view that if the total available budget is revealed on each sub-contract order, then the sub-contractor will be tempted to spend and claim costs up to that limit. If, on the other hand, the estimates are kept out of sight, progressing work within the

scheduled dates should suffice to stop the work from overrunning its budgeted costs.

Effective costs: a paradox When using about ten different sub-contractors for an engineering company in the British Midlands, one of us reached the following conclusions:

- all the companies chosen performed well in respect of their work quality;
- the terms for recovering expenses and for charging travel time varied considerably;
- the hourly work rates quoted varied considerably from one company to another;
- the hours actually booked for equivalent jobs also varied from company to company—in inverse proportion to the hourly cost rates.

Those companies which quoted the higher hourly rates were thus not necessarily the most expensive to use, because they tended to claim fewer hours and expenses for the equivalent amount of work. In fact, there was little actual variation in the real costs per task when using all these sub-contractors.

Special arrangements to protect standards and design quality If significant design packages are sub-contracted to external offices, there is a danger that the results might not properly match the project design concept, or that the solutions adopted would differ from those normally preferred by the project company.

Most reputable companies would not allow new permanent staff to work unsupervised on project design tasks or other vital work before undergoing some basic training and induction into the company's preferred practices and standards. The same argument applies to external staff entrusted with design tasks.

This problem can be overcome to a large extent by nominating one or more members of a sub-contractor's senior design staff as a 'key engineer'. Each key engineer can be invited to work in the contractor's main design office for a few weeks, working under competent guidance and absorbing the company's standards and practices.

A package of work is then selected for the external design office. The key engineer carries out the basic design and layout drawings for this work package in the project company's main office. When this work has been checked and approved, the key engineer returns to the external sub-contract office where he or she supervises other sub-contract staff in the detailing and checking of all the drawings needed to complete the work package.

As experience is gained, the main contractor will eventually allow some original design work to be carried out in the sub-contractor's office, regarding the key engineer as a kind of agent or external supervisor.

ROUTINE PRIORITY ALLOCATION IN MANUFACTURING PROJECTS

Occasions will often arise when work cannot be carried out by manufacturing departments in a sequence that suits every project schedule. If the production control department were able to pick up all orders and load them sequentially, or according to their own machine and manpower schedules, no serious problem need arise. Sooner or later, however, an order is going to be placed that is wanted urgently, and the production controller will be asked to displace other orders in favor of the newcomer.

ABC System of Priorities

Some organizations attempt to allocate order priorities, perhaps by labeling their works orders with the letters A, B or C (for example) to indicate the degree of urgency attaching to each order. A job carrying Priority A would be perceived as being more urgent than jobs at Priority B, leaving Priority C jobs as the poor relations. It is not difficult to imagine why such systems break down. Everyone will label their orders as A priority, so that everything is wanted at once and nothing receives special attention.

Wanted-by Dates

A preferable arrangement is to schedule manufacturing orders by 'wanted-by' dates. The production controller can then attempt to schedule to meet these dates, and warn those who are likely to be disappointed. If any project

item is expected to be delayed beyond its critical date, the possibility of sub-contracting the work can always be considered.

Resolving Conflicting Priorities

Special project work often has to take its place alongside routine manufacturing work or jobs for other projects. Conflicts can arise between jobs with different priorities, and it is a brave person who attempts to intervene between two rival project managers who are fighting for the same production resources.

Critical path analysis and multi-project resource scheduling are the logical ways for deciding priorities but, unfortunately, some managers are not over impressed with logical reasoning when they see their project being delayed (taking advantage of available float) in favor of other work. If such problems cannot be resolved on the spot without bloodshed, a sensible approach is to refer the problem to a third-party arbitrator—preferably a manager at a more senior level in the organization, capable of assessing the relative merits of the conflicting jobs.

WHEN THE NEWS IS BAD

How Bad?

When jobs start to run late, the first thing to be considered is the effect that this is likely to have on:

1. the current project;
2. projects or other work queuing in the pipeline;
3. last, but certainly not least, the customer.

On rare occasions, late running might be acceptable and require no action. Usually, however, some degree of corrective action is needed. The project manager must then assess the situation, decide the appropriate action and implement it.

Late jobs with free float If the recalcitrant work has enough free float to absorb the total expected delay, then all that needs to be done is to ensure that

the work is expedited and finished without further interruption, within the available free float time.

Late jobs with some total float Total float that contains no free float has to be regarded more seriously because any total float used up by late working early in the program will rob later tasks in the same logical chain of their float. So, those jobs which possess total float but no free float should, wherever possible, be expedited to bring them back on schedule.

Purchasing and manufacturing departments have always suffered at the hands of project managers by being expected to perform miracles when all the total float has been used up by late-running design tasks, long before work enters the purchasing and manufacturing phases.

Late jobs with zero or negative float If critical tasks (tasks with zero or negative float) are late, then clearly special measures must certainly be taken. It might be necessary to accept more expensive working methods to expedite these late jobs and bring them back on schedule.

If a task budgeted to cost $10 000 is in danger of running several weeks late and jeopardizing the handover date of a project worth $10 million, then obviously it would be worth spending $20 000 or even more on the problem task if that could rescue the project program. The project manager must always view the costs of expediting individual activities against the potential effect on the whole project.

CORRECTIVE MEASURES

Routine Measures

Corrective measures will only be successful if they are taken in time, which means that adequate warning of problems must be given. This will depend on monitoring progress regularly against a well-prepared schedule that is kept up to date.

Working overtime, perhaps over one or two weekends, can sometimes recover time. The project manager will be thankful, on such occasions, that overtime working was held back as a reserve and not built into the schedules as normal practice. Used occasionally, overtime can be an effective help in

overcoming delays. Used regularly or too often, however, the law of diminishing returns will apply, with staff permanently tired and working under pressure, leaving inadequate reserves for coping with emergencies.

If problems are being caused by shortage of resources, perhaps these could be made available from external sources by sub-contracting. Or, there might be additional capacity somewhere else in the contractor's own organization that could be mobilized.

The network logic should always be re-examined critically. Can some tasks be overlapped, bypassed or even eliminated? Is there any task that could wait until after the main part of the project has been delivered?

If all else fails, try to find out what the customer's reaction would be to late delivery. If, for instance, the project is to supply and install new machinery in the customer's brand new airport terminal, it could be that the customer's own building program is running late, so that the terminal cannot possible be opened as originally scheduled. There is no reason for any project manager to go berserk trying to deliver on time if that would simply mean the delivered equipment standing idle in the customer's stores for months before it can be used. In those circumstances a later delivery date can be negotiated for delivery of the new machinery with no one being inconvenienced.

Immediate Action Orders

One solution to the handling of really urgent priorities relies upon the use of special 'immediate action orders'. These are printed on highly distinctive card or paper, either brightly colored or covered with vivid red or bright orange stripes. Fluorescent ink is ideal, the brighter the better. An example is illustrated in Figure 22.5.

Special measures are necessary to ensure that a proper degree of urgency and respect is always afforded to immediate action orders:

1. Immediate action orders must be designed so that they stand out easily from all other documents, and cannot be ignored.
2. Each order must be authorized at very senior level (a nominated member of the company's top management).
3. Only one immediate action order may be in force at one time in the organization.

4. Immediate action orders must be hand-carried from department to department, and from work station to work station, with the date and time of entry and exit stamped against each operation.
5. Every department named for action on an immediate action order must give the specified work absolute priority and interrupt other work if necessary—*immediately.*
6. All possible means must be devoted to achieving the work, regardless of expense. For example, a vehicle or aircraft may have to be sent to collect vital components or materials from a supplier. Special prices might have to be paid to suppliers to compensate them for any urgent action.

An Immediate Action Order Case Example

A project for a complex defense weapons system was under way, part of which was an air-borne radar beacon. One of the components was a miniature 3000-volt transformer and, at the time of this incident, a single prototype was being made. The transformer was highly specialized, and required intricately machined parts, very careful winding and awkward assembly. Because of its small size and high voltage this transformer had to be encapsulated in epoxy resin before it could be used or even tested. Should it fail, it would be a complete write-off because none of the components could be recovered and used again.

The prototype transformer did indeed fail its insulation test. This left the project without a key component, and with a transformer design problem. The prototype had taken six weeks to produce, with rigid inspection stages imposed throughout because of the requirements of the government defense department. The idea of having to wait a further six weeks for a replacement, on top of the delay while the engineers sorted out the design problem, was simply out of the question.

The project manager prepared an immediate action order for design correction and manufacture of a new transformer. The order was authorized, but only after the project manager had convinced the company's top management that the transformer really was critical, and desperately needed.

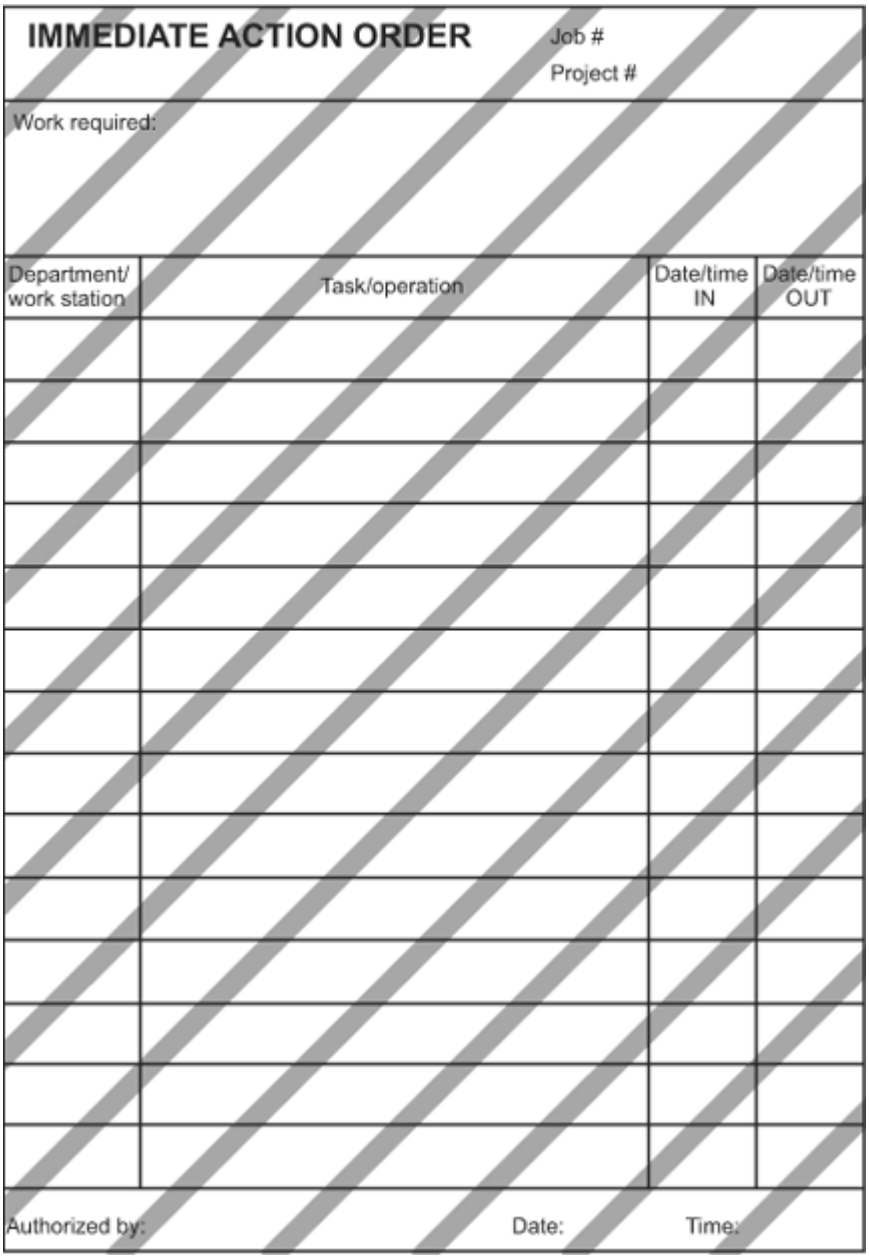


Figure 22.5 Immediate action order
Vivid orange stripes (shown here with shaded lines) make this document difficult to ignore.

The first result of issuing the immediate action order was to prevent the possibility of any further immediate action orders being issued. Only one was allowed to be in force at any time in that plant.

A progress chaser was assigned full time to the order, and he started by taking it to the chief design engineer, placing it on his desk, and stamping the date and time of arrival against the 'investigate failure and modify design' operation. The investigation was put in hand immediately and the failure of

the first unit was found to be due to air bubbles in the encapsulating resin. The engineers modified the design slightly to reduce the risk of air being trapped during the molding process. The presence of an impatient progress chaser with a time-stamp in his hand, the company president's signature, the vivid design of the order sheet, and the knowledge that a post-mortem examination would be carried out afterwards to look at all the in and out times caused such a flurry of activity that modified manufacturing drawings were ready and printed within about one hour of the immediate action order being signed.

When the order and the new drawings reached the manufacturing department, one operation required the use of a milling machine, but all machines were in use. Another job was therefore stopped and the workpiece was removed, half finished, from a milling machine to make way for the immediate action order. All the other components were made ready within a very short time, on the same day.

The quality management department had been warned in advance, and they inspected and passed the work without delay, but they did ensure that the required quality standards were maintained. The progress chaser stayed with the job, and continued time-stamping the order in and out of each department or work station, through winding, assembly, resin encapsulation and final testing.

The new transformer passed all its performance tests. Without the impetus given by the immediate action order, this job would undoubtedly have again taken at least six weeks. In fact it took only three days. Of course the cost was high, and might have been higher still had any special actions been needed to get materials. But the project program was saved. In total terms, the cost of crashing all the transformer activities was easily compensated for by the cost saving made in preventing a six-week slippage of the whole project.

The reasons why such dramatic success was achieved should be appreciated. In the first place, the order was rare and commanded immediate attention from all concerned. It was not 'just another high priority order' but was one of only about six issued by the company in a full year. Assigning a progress chaser to the job full time meant that no component was left unattended on a rack at any time to await collection and transport to its next operation. Further, the high level of authorization, together with the sense of urgency created by time-stamping the arrival and departure times for each

department, left absolutely no doubt in any mind regarding the genuine urgency of the crash action request.

If special cases for priority are to be allowed, these must be strictly limited in number. But, once any job has been given top priority status, then all the force and weight of management must be used to back up that decision and ensure that the job is carried right through without interruption. There must be no half measures.

MEETINGS

Purpose of Meetings

All who are concerned with aviation projects will know that too much time can be taken up by meetings. A client known to one of us seemed always to have its senior engineering staff locked in meetings but when this was pointed out to the engineering director his answer was: 'Whenever we have a problem we kill it with meetings.' That was a successful company, so maybe he had a point. There are many reasons for calling meetings. Meetings can be used to:

- inform;
- collect and discuss data;
- gather ideas through brainstorming;
- consider proposed changes;
- make rules and regulations;
- hear grievances;
- resolve disputes;
- allow fruitful debate;
- make collective decisions;
- solicit action;
- issue instructions and commands.

Perhaps it is not surprising that many organizations always seem to be plagued by having too many meetings. Different kinds of meetings encountered in projects include:

- pre-project sales meetings;
- project kickoff meetings;
- planning meetings;
- brainstorming to identify risks;
- cost estimating meetings;
- technical design meetings;
- ad hoc informal meetings;
- airport site meetings;
- change committee meetings;
- meetings with suppliers;
- meetings with sub-contractors;
- meetings with aviation regulatory bodies;
- meetings with a client or customer;
- regular progress meetings;
- irregular progress meetings (panic sessions);
- final handover meeting and celebration.

Administration of Meetings

The chairperson bears responsibility for the conduct and arrangement of meetings. The project manager will often be in the chair. Sufficient attention must be paid in advance to the administrative arrangements. Here is a checklist of desirable conditions:

- a meeting room of suitable size has been reserved;
- appropriate visual aids are in place and functioning;
- there is adequate ventilation;
- visitors are met and conducted with courtesy to the meeting room;
- messages and incoming telephone calls are not allowed to interrupt the proceedings (a telephone able only to make outgoing calls can be a useful feature);
- refreshments are provided, if appropriate.

All those invited to the meeting should be given an agenda in advance, so that they have time to prepare their contributions, arguments or exhibits.

Overnight accommodation might have to be arranged for delegates traveling long distances. Otherwise, meetings should not be timed to start too early in the day if that would cause inconvenience to visiting delegates (especially those from the customer).

Some argue that meetings should be scheduled for mid- to late-afternoon, so that there is an incentive to get proceedings over and done with as quickly as possible. On the other hand, people tend to be more alert early in the day, and more creative and collective brainpower is likely to be available then to deal with any difficult problems. The chairperson will have to decide which option is best for the particular occasion and the types of people expected to attend.

Resolving Arguments or Conflict

Arguments sometimes break out during meetings. These may not be altogether undesirable because meetings must be kept alive, with enthusiasm encouraged (provided always that any heat generated can be contained within extinguishable limits). However, arguments must be resolved within the meeting, so that agreement is reached before the members disperse. If that is not done, continuing friction can result, which is an entirely different condition from healthy enthusiasm and team cooperation.

In project work, responsibilities often fall between two or more departments, one of which can usually manage to lay blame at the other's door for any shortcomings or apparent negligence. Manufacturing problems or delays, for instance, might be blamed on poor design or on unreasonable rejections by inspectors. On some occasions these criticisms will have some foundation. At other times they will not. When such conflicts arise they must be resolved quickly. Unprofitable stalemate conditions must not be allowed to persist and disrupt team harmony.

The chairperson has a clear duty to discover the true facts which underlie any interdepartmental or interfunctional problems, not so much to apportion blame as to ensure the continued progress of the project for which he or she is responsible.

Sometimes an impasse is reached where two departmental managers give separate and conflicting accounts of the reasons for a common problem. There is only one way in which to overcome such arguments. The opposing individuals must be allowed to confront each other in the presence of a

responsible mediator, which in this case will usually be the chairperson. Individuals should now be more reluctant to make excuses that distort the exact truth, because they know that instant denial of any unjust criticism will be forthcoming from the opponent.

More constructively, the person-to-person discussion possible in meetings removes the communication delays that exist between impersonalized departments, often allowing solutions or compromises to common problems to be agreed on the spot.

Was the Meeting Successful?

When a meeting breaks up, it will have been successful only if all the members feel that they have achieved some real purpose and that actions have been agreed which will benefit the project. Demands made of members during the meeting must be achievable, so that promises extracted can be honored.

Issuing the Minutes

Publication of the minutes must be undertaken without delay in order that they do not become outdated by further events before distribution. Minutes should be clearly and concisely written, combining brevity with clarity, accuracy and careful layout, so that each action demanded can be seen to stand out from the page. Documents that are too bulky may not even be read by everyone. Short, pointed statements of fact are all that is required.

No ambiguity must be allowed after any statement as to who is directly responsible for taking action. Every person listed for taking action must receive a copy of the minutes (an obvious point that is sometimes overlooked). Times must be stated definitively. Expressions such as ‘at the end of next week’ or ‘towards the end of the month’ should be avoided in favor of actual dates.

A Simple but Effective Meetings Control Procedure

Bentley (1976) described a simple form and set of rules which are very effective for the management of meetings. The control form, an adaptation of Bentley’s design, is shown in Figure 22.6.

The person responsible for calling the meeting fills in the agenda on one of these special forms and lists all those invited to attend (after telephoning as many of them as possible to check that the proposed time and place will be convenient). Copies of the form are then distributed to all the members, preferably several days in advance of the meeting.

When the meeting takes place, one copy of the special form is used to record the proceedings. The procedure is so simple that no secretary is necessary, and the chairperson can fill in the details as the meeting progresses. The first action is to tick the names of those who actually attend. Decisions and actions agreed during the meeting are written on the chairperson's copy during the progress of the meeting. A glance at Figure 22.6 shows that spaces are provided for this purpose.

Just before the meeting breaks up, the chairperson's copy of the form, now complete with all its annotations, is photocopied. All members of the meeting are given a copy as they leave. Thus instant issue of the minutes is achieved. All the decisions taken and actions are recorded exactly as they were agreed during the meeting, fresh in people's minds.

Meeting action sheet	Meeting/project reference number:	
Date, time and place:		
Those to attend: Meeting called by (chairperson):		
Purpose of meeting and agenda:		
Decisions agreed:		
Actions agreed:	Action by:	Action when:

Figure 22.6 A combined meeting agenda and action sheet
These action sheets are great time savers. They allow the minutes to be issued when meeting closes. *Source:* After Bentley, T., (1976), *Information, Communications and the Paperwork Explosion*, Maidenhead, McGraw-Hill.

Progress Meetings

Any project manager worthy of the title will want to make certain that whenever possible tactics are preventative rather than curative. If a special meeting can be successful in resolving problems, why not pre-empt trouble

by having regular progress meetings, with senior representatives of all departments present?

Regular progress meetings provide a forum where essential two-way communication can take place between planners, managers and other project participants. The main purposes of progress meetings emerge as a means of keeping a periodic check on the project progress, and the making of any consequential decisions to implement corrective action if program slippages occur or appear likely to occur.

There are some dangers associated with the mismanagement of progress meetings. For instance, it often happens that lengthy discussions arise between two specialists on technical issues that should be resolved outside the meeting. Such discussions can bore the other members of the meeting, waste their scarce and expensive time, and cause rapid loss of interest in the proceedings. Although it is never possible to divorce technical considerations from progress topics, design meetings and progress meetings are basically different functions which should be kept apart. Discussions should be kept to key progress topics, with irrelevancies swept aside.

The frequency with which meetings are held must depend to a large extent on the nature of the project, the size and geographical spread of its organization, and its overall timescale. On projects of short duration, and with much detail to be considered, there may be a good case for holding progress meetings frequently, say once a week, on an informal basis at supervisor level. For other projects, monthly meetings may be adequate. Meetings at relatively junior level can be backed up by less frequent meetings held at more senior level. Project review meetings, which can cover the financial prospects as well as simple progress, can also be arranged—the company's general manager may wish to attend such meetings and for some capital projects the customer might also wish to attend or be represented.

Meetings held more frequently than necessary create apathy or hostility. Supervisors and managers are usually busy people whose time should not be wasted.

A Case Example of Progress Meetings Abandoned

The above account of progress meetings adheres to the conventional view that progress meetings are an accepted way of project life. Here is some food

for less conventional thought from our direct experience.

An engineering company had long been accustomed to holding progress meetings. Depending on the particular project manager, these were held either at regular intervals or randomly whenever things looked like going badly adrift (most readers will have encountered such 'firefighting' meetings). Several projects were in progress at any one time, and the permanent engineering department of about 60 people was often augmented by as many as 80 sub-contracted staff working either in-house or in external offices.

Meetings typically resulted in a set of excuses from participants as to why actions requested of them at previous meetings had been carried out late, ineffectually or not at all. Each meeting would end with a new set of promises, ready to fuel a fresh collection of excuses at the next meeting. This is not to say that the company's overall record was particularly bad, but there was considerable room for improvement and too much time was being wasted at meetings.

Senior company management, recognizing the problem, supported a study which led to the introduction of critical path network planning for all projects, using a computer to schedule resources on a multi-project basis. The computer printed out detailed work-to lists, filtered and sorted for the attention of the relevant departmental managers. This targeted distribution was made possible by filtering and sorting the computer output reports using well-designed WBS and OBS codes.

Two progress engineers were engaged. One of these was appointed to follow up in house work and the other to supervise outside sub-contractors. Both engineers had the benefit of the detailed work-to lists, which told them exactly:

- all jobs that should be in progress at any time;
- the scheduled start and finish dates for these jobs;
- how many people should be working on each job;
- how many people should be working in total on each project at any time;
- the amount of remaining float available for every job.

By following up activities on a day-by-day basis in accordance with the work-to lists, these two progress engineers succeeded in achieving a

considerable improvement in progress and the smooth flow of work. If critical or near-critical tasks looked like running late, the relevant supervisors or managers were informed and they pulled out all the stops to bring progress back into line (by working overtime during evenings and weekends if necessary). Fortunately, all the staff were cooperative. Eventually they became grateful for the new sense of order created in their working lives.

After several months under this new system it dawned on all the company managers that they were no longer being asked to attend progress meetings. Except for kickoff meetings at the introduction of new projects, progress meetings had been made unnecessary.

PROGRESS REPORTS

Internal Progress Reports to Company Management

Progress reports addressed to company management must set out the technical, fulfillment and financial status of the project and compare the company's performance in each of these respects with the scheduled requirements. For projects lasting more than a few months, such reports are usually issued at regular intervals, and they may be presented by the project manager during project review meetings.

Discussion of a report might trigger important management decisions that could lead to changes in contract policy or project organization. For this and many other reasons it is important that data relevant to the condition and management of the project are presented succinctly and factually, supported where necessary by explanations and forecasts.

Internal reports often contain detailed information of a proprietary nature. They might, therefore, have to be treated as confidential, with their distribution restricted. This is particularly true of many aviation projects, especially where these are connected with national defense.

Progress Reports to the Client or Customer

The submission of formal progress reports to the client or customer could be one of the conditions of contract. If the customer does expect regular reports

then, quite obviously, these can be derived from the same source that compiled all the data and explanations for the internal management reports. Some of the more detailed technical information in the internal reports may not be of interest to the customer or relevant to its needs. Customer progress reports, therefore, are often edited versions of internal management reports.

Whether or not financial reports accompany customers' progress reports will depend on the main contractor's role in each case. Under some circumstances cost and profitability predictions must be regarded as proprietary information, not to be disclosed outside the company. In other cases, the project manager may have to submit cost summaries or more detailed breakdowns and forecasts as part of an advisory service to the customer.

Although customer reports may have to be edited in order to improve clarity and remove proprietary information, they must never be allowed intentionally to mislead. It is always important to keep the customer informed of the true progress position, especially when slippages have occurred that cannot be contained within the available float. Any attempt to put off the evil day by placating a customer with optimistic forecasts or unfounded promises must eventually lead to unwelcome repercussions. Nobody likes to discover that they have been taken for a ride, and customers are no exception to this rule.

REFERENCES

Bentley, T., (1976), *Information, Communications and the Paperwork Explosion*, Maidenhead, McGraw-Hill.

23
Managing Changes

No aviation project can be expected to run from start to finish without at least one change. The exception to this rule might exist as a project manager's dream of Utopia, but is unlikely to assume any more tangible form. Our definition of a project change is:

> a departure from the authorized project scope or design as indicated by a change to any drawing, specification or main contract *after its approval and first issue for action*.

SPECIAL REASONS FOR MANAGING CHANGES IN AVIATION PROJECTS

People, as a rule, do not like change. Once they have their minds set on a target they like to see a clear path towards achieving it. Those who have learned to like their jobs and feel secure suffer shock when they are asked to change the way in which they do those jobs or, worse still, are told that they are no longer needed and must look elsewhere for employment. Changes are disruptive. Project changes are no exception, and are generally to be discouraged, even though some changes can be beneficial. Clearly changes demanded by a customer must usually be honored but there must be some filter in the system that blocks unnecessary or undesirable changes. Changes should be restricted to those that are essential for performance, safety or reliability. This chapter is principally about that change filter system or, in other words, change management.

Change management has another important dimension beyond filtering out undesirable changes and that is version control. All users of software are conscious that the version of the software loaded in their computers can have a dramatic effect on the use and performance of that software. In some industries (including aerospace and aviation) version control is important for maintenance, reliability and safety. In all aviation software and hardware

products (by which we mean anything from discrete components to complete aircraft) every modification incorporated has to be recorded to ensure version control. There must be a record kept in a secure place to log which changes have been incorporated in every program, plane or aviation component. This extends beyond the initial project life cycle to changes made whilst the product is in service with the end-user.

THE IMPACT OF CHANGES IN RELATION TO THE PROJECT LIFE CYCLE

Changes are usually unwelcome to a project manager at any stage, but changes that occur toward the end of a project have the potential to cause far greater cost and disruption than those that are agreed before the project begins.

When a project is in its proposal or business plan stage, any proposed change in the scope or nature of the project may cause some annoyance and result in more investigations, revised financial appraisals and fresh planning. However, the same change when a project is active and nearing completion would be disastrous because much of the work in progress or completed would have to be scrapped and restarted. Any live project has both sunk costs (the costs of work already done and materials bought) and costs remaining to completion. Sunk costs are always at risk when a change is made.

Thus it is a general rule that the later the change happens in the project life cycle, the greater the cost and disruption it will cause. This is illustrated in Figure 23.1.

ORIGIN AND CLASSIFICATION OF CHANGES

Changes can arise from a customer's request that changes the project scope or specification, a self-inflicted engineering design modification, or through some reason during work on the project that causes the finished result to differ in some respect from the issued drawings, specifications or other formal instructions. Changes (and therefore change management) can sometimes be needed even after the project has been finished and handed

over to the customer. Figure 23.2 shows many routes through which changes can develop in an aviation manufacturing project.

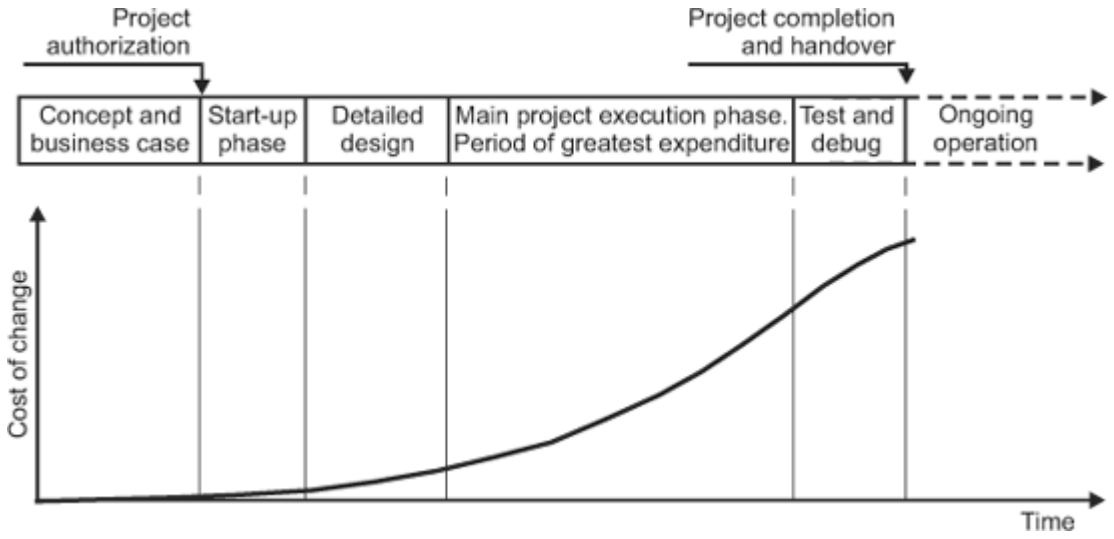


Figure 23.1 The cost of a given project change relative to the project life cycle

Classification of Changes

Changes that concern the project manager can usually be placed in one of two principal commercial categories namely:

1. changes originating from within the project organization without any involvement from the customer or client;
2. changes requested by the customer or client.

There are some borderline project change cases which cannot be put into either of these two classifications but which contain elements of both.

We must also mention post-project changes here. These are changes that do not affect a project or its progress and occur after the initial project has finished. The most common occurrence of these is seen when changes are made to aircraft that are already in service to improve their reliability or safety. Such changes will have to be made in the field and, if the particular aircraft type is still in production, back at the manufacturing plant, then the change must also be made to current production. These changes are not strictly speaking project changes and they fall outside the remit of the project manager (who, by now, will have moved on to other pastures). Nonetheless

some aspects of project change management will apply to these post-project changes in order to preserve traceability and version control.

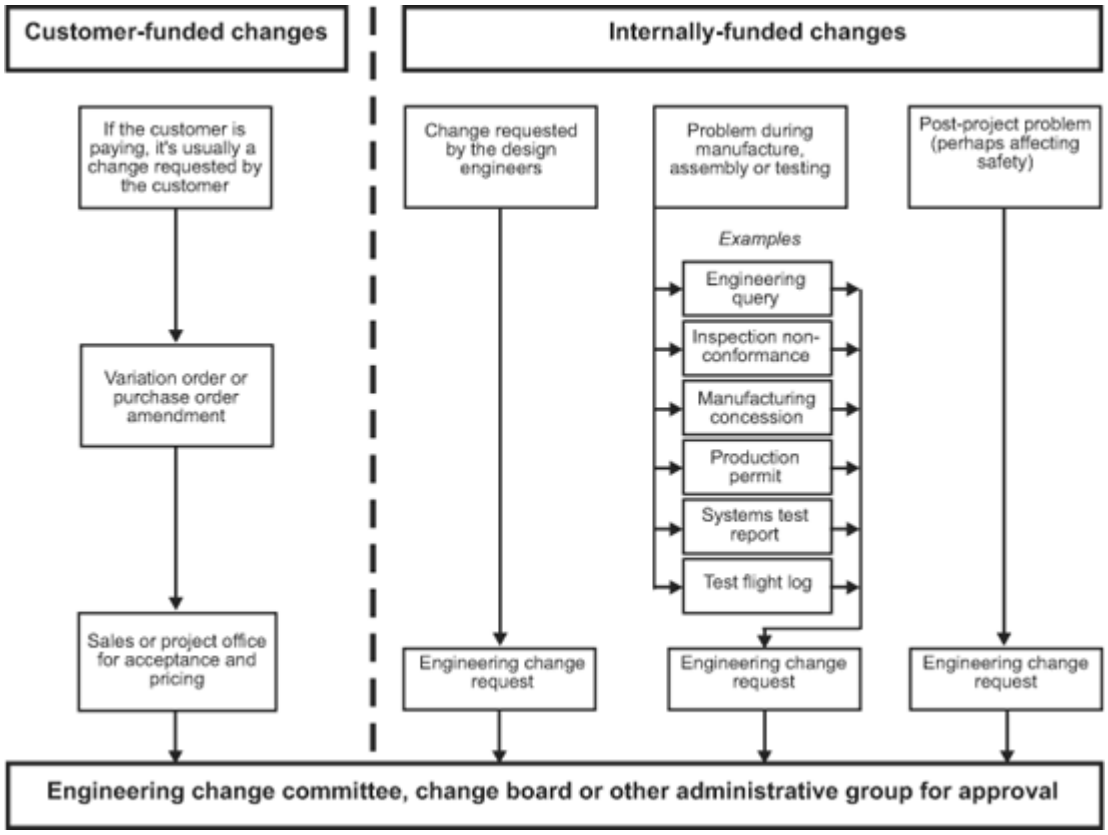

Customer-funded changes
Internally-funded changes
If the customer is paying, it's usually a change requested by the customer
Change requested by the design engineers
Problem during manufacture, assembly or testing
Post-project problem (perhaps affecting safety)
Examples
Engineering query
Inspection non-conformance
Manufacturing concession
Production permit
Systems test report
Test flight log
Variation order or purchase order amendment
Sales or project office for acceptance and pricing
Engineering change request
Engineering change request
Engineering change request
Engineering change committee, change board or other administrative group for approval

Figure 23.2 Possible origins of changes in an aviation project

A more useful way of classifying changes from the commercial and project management point of view is to label them as ‘funded or ‘unfunded’. For a funded change the customer must take responsibility for the change and pay for it. For unfunded changes the contractor or manufacturer will have to absorb all the costs, with consequent risk to budget limits and expected profits. Whether or not a change is to be funded or unfunded will greatly influence how it is considered for authorization.

Funded changes Changes to the specified project requested by the customer automatically imply a corresponding change to the contract, since the project specification should form part of the contract documentation. If, as usually happens, the modification results in an increase in the contractor’s costs, a suitable change to the contract price must be negotiated. The delivery

schedule may also be affected and any resulting delays must be predicted, discussed and agreed.

Customer-funded modifications may possess nuisance value and can disrupt the smooth flow of logically planned work, but they do nevertheless offer the prospect of compensation through an increase in price and possibly an increase in profit. When a customer asks for a change, the project contractor is in a strong price-bargaining position because there is no competitor and the contractor has a monopoly. It is possible that a project which is heading for a financial loss to the contractor can be rescued and brought back into profit if the customer asks for changes, especially if those changes occur late in the production program.

Customer-funded changes are usually documented as purchase order amendments or contract variation orders (otherwise known as contract variations or project variations).

Unfunded changes If a contractor finds it necessary to introduce changes for reasons unconnected with the customer, it is hardly likely that the customer could be expected to pay (unless the changes are covered by some contingency for which provision was made in the contract). The contractor must be prepared to carry the additional costs, write off any scrapped work and sunk costs, and answer to the customer for any resulting time delay. For these reasons, contractors have to be particularly cautious about allowing unfunded changes to proceed.

The description ‘unfunded’, although in common use, is not strictly correct because every change must be paid for somehow. So in this sense ‘unfunded’ really means funded from within the project organization. In other words unfunded changes are those paid for by the contractor where the costs cannot be recovered from the customer.

The procedure for introducing an unfunded modification into an active project usually starts by raising a document called an engineering change request, engineering change order, modification request or some permutation of these terms. Some reasons for unfunded changes are shown in Figure 23.2 and the relevant documentation is described later in this chapter.

Permanent and temporary changes Changes can be further classified as permanent or temporary.

Permanent changes are carried out with the intention of leaving them permanently embodied in the design and execution of a project. These changes will remain recorded in drawings and specifications to show the true as-built condition of the completed project.

Temporary changes may be needed for expediency in getting a project finished, but they are carried out with the intention either of removing them or converting them to some alternative permanent change at a later, more convenient time.

AUTHORIZATION ARRANGEMENTS

The effects of any change, whether customer-requested or not, may be felt far beyond the confines of the project area that is most obviously and directly affected. This could be true of the technical, timescale or cost aspects. Most projects have to be regarded as a combination of technical and commercial systems, in which a change to one part can react adversely or beneficially with other parts of the system. Such inter-reactions can bring about consequences that the change's originator may not have been able to foresee.

For these reasons alone it is prudent to ensure that every proposed change is considered and approved by selected key members of the project organization before it can be implemented. This precaution should allow the overall effects to be predicted as reliably as possible. These selected key members form the 'change committee' or 'change board'. In some organizations, perhaps in larger companies, the change committee might be a properly constituted body that meets regularly in formal meetings. In small project organizations the arrangement is usually far less formal, but there must nevertheless be some recognized procedure for change consideration and approval at senior level.

The Change Committee or Change Board

In many companies engaged on aviation projects a regular panel of experts is appointed to consider changes and decide how they are to be handled.

Managers in or represented on the committee must include those who are able to answer for the following potential effects of each change on:

- safety;

- reliability in service;
- performance;
- cost;
- work in progress and sunk costs;
- relevant sub-contracts and purchase orders;
- feasibility or difficulty of introducing the change into manufacture or construction;
- point of embodiment (in other words, when projects result in more than one product or batches of products, should the change be applied):
  – only to units not yet started in production;
  – to work in progress and all future units;
  – to all units ever produced or likely to be produced (which would mean retrospective action to modify units already in service with end users).

A change committee or change board will usually have, as a minimum, the following members:

- the *design authority*—typically a design manager or chief engineer;
- the *inspecting authority*—a person such as a quality manager who should be independent and able to make assessments on the basis of quality alone, without commercial pressure. This function may be overseen by a national regulatory authority.

A change committee might also include senior members of the manufacturing and purchasing departments, to help the committee decide on how a proposed change might impact on work in progress, ease of manufacture and purchase order status.

Change Committee Meetings

Change committees for large projects often meet on a frequent, regular basis, dealing with change requests in batches. Others avoid meetings by circulating requests around the committee members, so that each member considers the effect of the proposed change on their own area of responsibility. Each method has its advantages and disadvantages. If formal committee meetings take place at monthly intervals, the wait for change decisions can hold up

project progress or result in the greater disruption to work that late changes cause. On the other hand, very frequent committee meetings take up too much members' time. Informal committees, not meeting collectively but relying instead on the circulation of documents, suffer from a communication problem and can take longer to discuss and resolve misunderstandings or make decisions. Neither approach can be classified as right or wrong, but it will be assumed here that a formal procedure exists, with a change committee meeting at regular intervals (perhaps weekly on large projects with the potential for many changes, and monthly for smaller projects).

Decision Criteria

When each change request is considered for approval, the committee must weigh up all the possible consequences before making its decision (we know that the following checklist repeats some points already listed above):

- Is the change actually possible to make?
- Is it a customer-requested or a self-inflicted change?
- What is the estimated cost of the change?
- If the customer will pay, what should be the price?
- If the change is not customer-requested, is it really necessary? Why?
- What will be the effect on the project timescale?
- How will safety, reliability and performance be affected?
- If several identical sets of equipment are being produced, at what point in the production sequence should the change be introduced?
- Will scrap or redundant materials be created?
- Are any items to be changed retrospectively? Are these:
  - In progress?
  - In stock?
  - Already delivered to the customer or otherwise built into the project?
- What drawings, specifications and other documents will have to be modified?

Figure 23.3 illustrates some of the steps in the change handling process.

The Change Committee's Response

When the committee has considered all these questions, it has the following options:

- authorize the change as requested;
- give limited approval only, authorizing the change with specified limitations;
- refer the request back to the originator (or elsewhere), asking for clarification or for an alternative solution;
- reject the change, giving reasons.

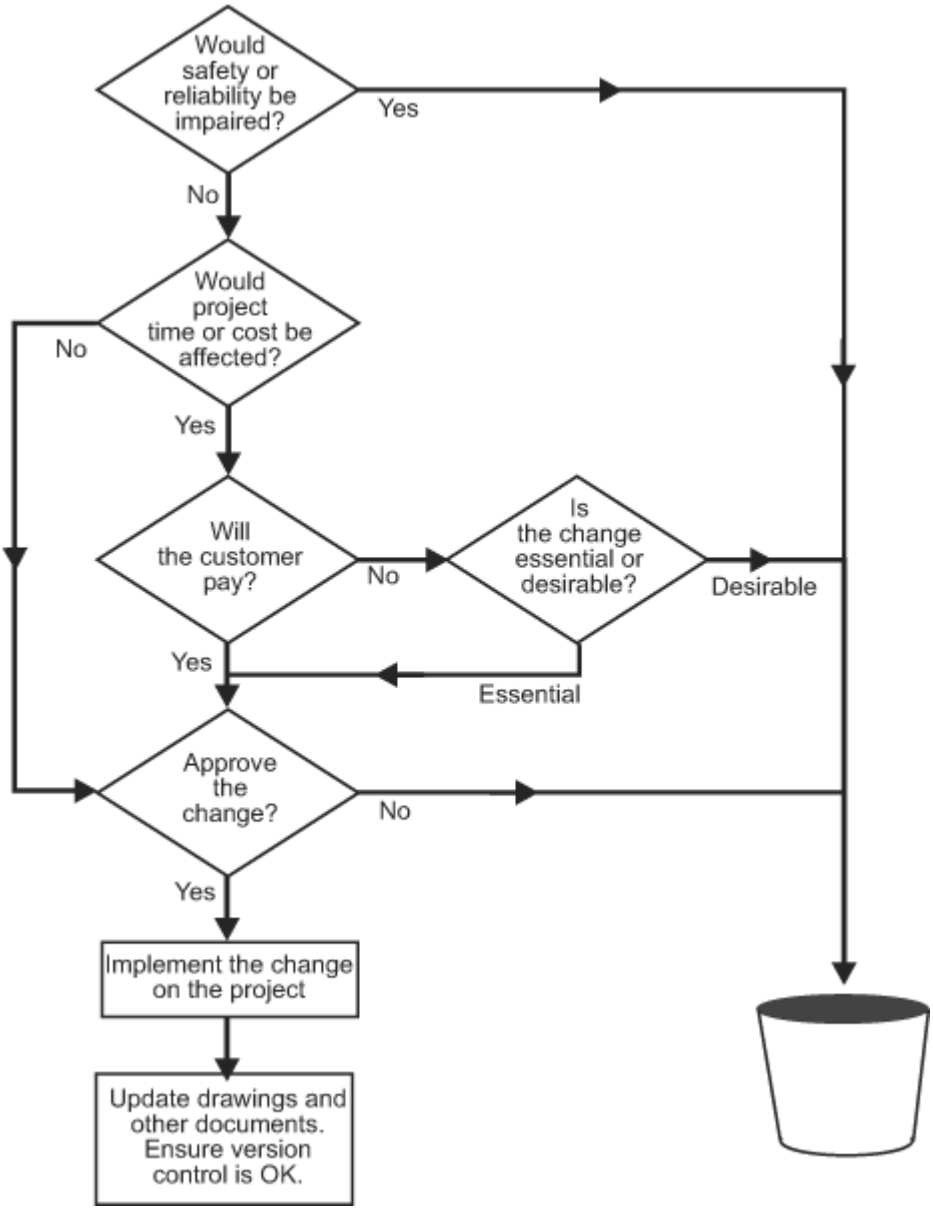


Figure 23.3 A typical change request procedure

GENERAL ADMINISTRATION OF PROJECT CHANGES

Use of Standard Change Request Forms

Individuals who wish to request a change should always be asked to put their request in writing. This chapter is written on the assumption that all such requests will be addressed to a change committee. Where the organization does not operate a formal change committee, a suitably senior member of the organization, such as the chief engineer, should be designated as the person responsible for considering and authorizing changes.

To save the committee's time and to ensure that all requests are properly controlled and progressed, some kind of standard change request form must be used. This form should be designed in such a way that the originator is induced to answer in advance all the questions that the change committee will want to ask.

Because there are several different routes along which changes can arise within any organization (see Figure 23.2) there are usually several different corresponding forms that can result in change requests. Some of these are illustrated later in this chapter, in the section 'Forms and procedures'. However, the administration procedures described here are generally applicable to all of these different forms.

Change Coordinator

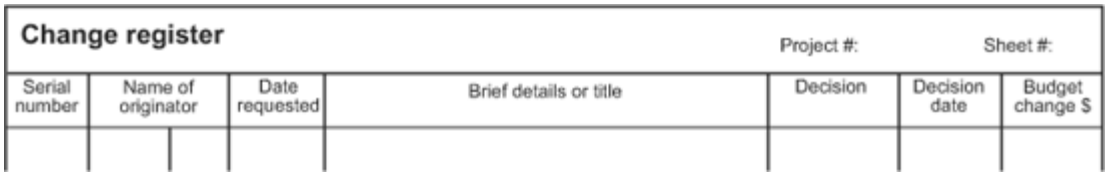
In any project organization where changes are expected (which really means all project organizations) it is advisable to nominate a change coordinator. This is not usually a full-time role, and the person chosen will probably carry out other clerical or administrative duties for the project. The change coordinator may reside in a contracts office, the project manager's administration group, a project support office, the engineering department or in some other department. The change coordinator's duties are likely to include:

- registering each change request and allocating it an identifying serial number;

- distributing copies of the change request to the change committee members;
- filing a reference copy of the change request;
- following up to ensure that every request is considered by the change committee without avoidable delay;
- distributing and filing copies of the change documents after the committee's instructions have been given (and annotated on the original request form);
- following up to ensure that the committee's instructions are carried out;
- following up to ensure that all affected drawings and specifications change are updated and reissued.

Both for the purposes of progressing each change request to ensure speedy resolution and for subsequent as-built project definition the change coordinator should maintain a change register (sometimes called a change log).

Change registers can be pages in a loose-leaf folder or, subject to safeguards against accidental erasure and loss, they can be held in a computer. Separate registers should be kept for project variations, engineering change requests, engineering queries, production permits and inspection reports. Usually a slightly different register format is used for each of these registers, but Figure 23.4 shows a fairly typical layout for a register page.



Change register Project #: Sheet #:

Serial number	Name of originator	Date requested	Brief details or title	Decision	Decision date	Budget change $

Figure 23.4 Typical arrangement for a project change register

Numbering and Registration

Apart from their initial use in allocating serial numbers, change registers are important for several other reasons, which include the following:

- to provide a base from which each change request can be progressed through all its stages, either to rejection or to approval and full documentation and implementation;
- to record changes in budgets and, if appropriate, prices so that the current valid budgets and prices will always be known;
- to provide a search base that allows tracking back ('traceability') so that the origins of all design and commercial changes can be found or verified, both during the life of the project and afterwards.

The change coordinator must allocate serial numbers from the appropriate register. The numbering systems should be kept simple, but must be designed so that no number is repeated on another project or in another register. The simple solution is to prefix each change with either the project number or a shorter code that is specific to the project, and to add one or two letters which denote the type of change. For example, if the project number is P123, engineering change request forms might be numbered in the series P123/ECR001, P123/ECR002, P123/ECR003 and so on. Concessions or production permits for the same project could be numbered in the series P123/PP001, P123/PP002, P123/PP003 and so on.

Progressing

To prevent undue delays, or even the risk of forgotten requests, change registers should be designed to highlight all those requests that are 'active'. That means all requests which have yet to be approved or rejected. For example, a column can be provided on the register sheet headed 'final issue date' or something similar. The absence of a date in that column tells the coordinator that the change is still active and in need of monitoring and progressing.

Ideally, the coordinator should be able to use the registers to follow up the action after approval, to ensure that the relevant drawings and specifications are updated and reissued.

Assessing all the Possible Cost Factors of a Proposed Change

Just as changes tend to cost more later in the project cycle, so they become more difficult to evaluate as project time passes. In an ideal world

individuals would include all possible costs of each proposed change in their estimates. Unfortunately the project manager must expect that some cost factors will be overlooked, whilst others might be impossible to evaluate. Checklists and searching questions can help to reset an estimator's train of thought:

- Is there to be no inspection and retesting on this job?
- Will existing stocks be affected?
- Will there be any purchase order cancellation costs?
- Will this change affect the prototype too?
- What about work in progress—how much of that will have to be scrapped and done again?
- How much will all the resulting delays cost?

Such questions must always be asked about the possible costs of changes, but the true answer will often be very difficult or impossible to establish. Nevertheless, an estimate of sorts can be made in most cases, and this can be used to work out and justify any possible increase in price that the contractor feels able to demand from the customer where that would be justified.

Recording the actual costs of a change can prove to be a far more difficult undertaking. Very often it is impossible to separate the costs attributable to a change from other task costs. Difficulties underlying the measurement and recording of actual modification costs may not always be appreciated by some managers and others who, quite reasonably, would like to know exactly how much their budgets are being affected by changes. Those managers may have to be disappointed, but it should always be possible to make a notional estimate of the cost of any change.

Case example Suppose that a modification is to be performed on a 'fuzzelbox', which is a complex piece of electronic equipment containing over 1 km of wire, thousands of electrical connections, piping and valves and many other components.

First, take the case where the fuzzelbox has already been assembled, inspected and fully tested. Here there need be no problem in identifying the cost of the change, because a fresh works order or job ticket can be issued for the modification work and materials, complete with a new cost code. All

the subsequent work of stripping, changing, inspecting and retesting can be attributed directly to the change.

Now consider the different (but frequent) case in which drawings and specifications are modified during the course of manufacture. The fuzzelbox is in a semi-completed state, so that the modification will add new wires, delete others, re-route wires and pipes not yet installed and result in changed connections and components. How can anyone be expected to record accurately that part of the work which is directly attributable to the modification?

It is quite possible that many changes will occur on a job of this size before it is finished, so that the only apparent and measurable effect on costs will be an increase of expenditure compared with the initially estimated production costs. This situation has to be accepted and, if the modification costs are needed for any purpose, they will have to be estimated.

FORMS AND PROCEDURES

This section describes in greater detail some of the routes through which changes can reach a project, together with their origins and associated forms (these routes were first illustrated in Figure 23.2). The authorization and general administration procedures already described in this chapter will apply generally to all of these forms.

Is a Formal Change Procedure Always Necessary?

Every rule has its exceptions and so it is with change control, where rigid procedures must not be allowed to override commonsense.

When a designer, in a fit of rage or despair, tears up a drawing or clears the computer screen and starts again, there is no prima facie need to invoke a formal change engineering procedure. Any new design might have to undergo many such interruptions and changes before it is committed to a fully-checked and issued drawing. This is all part of the normal creative development process. Provided that the design intentions remain within the requirements of the design specification, any internal changes made before drawings are formally issued are not generally considered to be modifications or engineering changes, even though they might prove expensive in lost time.

Some companies circulate early, pre-issue drawings for discussion, advance information or approval. These issues are often distinguished from the fully released versions by labeling them as issue A, issue B and so on, changing the revision issue numbers to the series 0, 1, 2 and so on to denote official releases. A rule might, therefore, be suggested that formal engineering change procedures need only be applied to drawing revisions made after the first issue for manufacturing or construction.

There are occasions where drawing errors are so apparent that the only recourse is to recall the drawings and reissue them without delay—there can be no question in those circumstances of any difficulty with version control or scrapped work because the original drawings were so much in error that no product could be manufactured. So to invoke a formal change procedure in those circumstances would only waste time and money.

One reason for invoking formal procedures is found whenever there is an intention to depart from the design specification, especially when the development work is being carried out for an external customer. Here is a case for using the formal change procedure before any drawing has been issued for manufacture or construction.

Some rule or criterion is needed that can determine at which point in the design process the formal change procedure should be introduced. The key question to be asked is 'Will the proposed change affect any instruction, specification, plan or budget that has already been agreed with other departments, the customer or other external organization?' If the answer to this question is 'Yes', the probability is that formal change committee approval will be needed.

Design Freeze

Sometimes project organizations recognize that there is a point in the design and fulfillment of a project after which any change would be particularly irksome, inconvenient or potentially damaging. This leads to the announcement of a 'design freeze', after which the change committee will refuse to consider any change proposal unless there are compelling reasons, such as safety or a customer request. Ideally the customer should also agree to be bound by the design freeze. In some companies the design freeze stage is called 'stable design'.

Project Variation Orders

Changes requested by the customer which affect price, delivery or any other aspect of the original purchase order or contract require formal documentation. The request document will fulfill the following functions:

- amend the purchase order or contract and describes the change;
- authorize the contractor to make the change;
- record agreement to any associated timescale revision.

Where the original contract was in the form of a purchase order, the customer will usually request a change by issuing a purchase order amendment. In other cases, especially for projects involving construction, changes are recorded on project variation orders (sometimes called simply 'project variations' or 'contract variations'). Similar changes arranged by a main contractor with site construction sub-contractors are often known as site variation orders.

A Quick Procedure for Simple, Repetitive Project Variations

In projects where a considerable number of small changes are expected, it may be possible to streamline all the change procedures, perhaps with a prearranged scale of charges. Naturally such a procedure must be restricted to changes of a routine nature, where safety and reliability cannot be affected. Provided that the scope of a change can be defined adequately, and that the work can easily be identified separately from other project work, the costs of small changes can be recovered on some agreed time and materials basis or, for construction projects, against an agreed schedule of rates per units of measured work.

Case example A contractor was engaged on a defense contract for designing and building automatic test equipment for the electronic systems installed in military aircraft. Each complete tester was housed in a trailer which could be towed out to an aircraft, connected by cables and left to carry out a whole range of measurements, 'go' or 'no-go' checks and diagnostic fault-finding routines.

Every time the aircraft manufacturer (the customer) wanted to change any of the test parameters a small amount of software reprogramming was necessary in the test equipment. This happened many times during many months of prototype commissioning at an airfield. Some changes also required one, two or three wires to be re-routed as quick temporary fixes. Attempting to estimate the cost of each of these hundreds of changes and subjecting all of them to a formal change committee procedure was out of the question. Yet every change had to be recorded for incorporation into manufacturing drawings, and somehow the contractor had to recover the additional costs.

These difficulties were resolved by both companies agreeing to a set common price for all these trivial program changes. Simple, serially numbered, all-one-price, program change request forms were printed in triplicate on serially numbered no-carbon-required pads for use at the airfield. These documented the technical details of each change, were authorized by the signature of the customer's engineer and accepted for on-the-spot action by the contractor's senior commissioning engineer. One copy of each change form was kept by the customer's engineer, and another was returned to the contractor's head office, where the relevant drawings and programming records were updated at regular intervals.

Weekly invoices were sent to the customer listing the serial numbers of all the changes in each batch. No technical details or descriptions were needed on the invoices, which were priced simply by multiplying the number of changes made each week by the standard price. The system was limited by mutual agreement to include only the simple changes to measurement parameters and test-point switching. Many hundreds of these changes were requested, actioned and billed using these very simple pre-priced request forms. That saved valuable time at the commissioning site, with the contractor collecting a satisfying level of revenue and the customer freed from the expense of preparing, negotiating and issuing a formal contract variation for every change.

Engineering Change Requests

The purpose of an engineering change request is to describe, document and seek formal permission for a permanent design change. The change may be unfunded, or it might be the result of a project variation order and, therefore,

funded. Engineering change requests of the type shown in Figure 23.5 are used widely in engineering projects, although they may be known by different titles, invariably abbreviated to sets of initials. The following are among those which may be encountered:

- ECR—Engineering Change Request.
- ECO—Engineering Change Order.
- MR—Modification Request.

There is no reason why any person, however junior, should not be allowed to originate an engineering change request because it can have no effect until it has been authorized by the change committee. The method for completing the form should be self-evident from Figure 23.5.

Concessions or Production Permits

Manufacturing departments, faced with the need to keep to a budget or to accomplish work within a scheduled timescale, sometimes find that they need to depart from the specific instructions contained in the manufacturing drawings to achieve their objective. Naturally, the quality control department will keep a wary eye open to ensure that no unauthorized shortcut or botching is allowed.

Suppose, however, that a drawing specifies the use of high tensile steel bolts, but that these are simply not available when required. The purchasing department may be able to obtain alternative bolts that are not high tensile, or possibly some other thread size could be substituted. If the production team decided to make this substitution without reference to the design engineers, the relevant inspector should notice the substitution and reject the work because it deviated from the drawing.

But would the use of these alternative bolts really matter? It all depends, of course, on the actual circumstances and whether or not the bolts are going to be subjected to high tensile stress. Someone has to decide, and either authorize or reject the change.

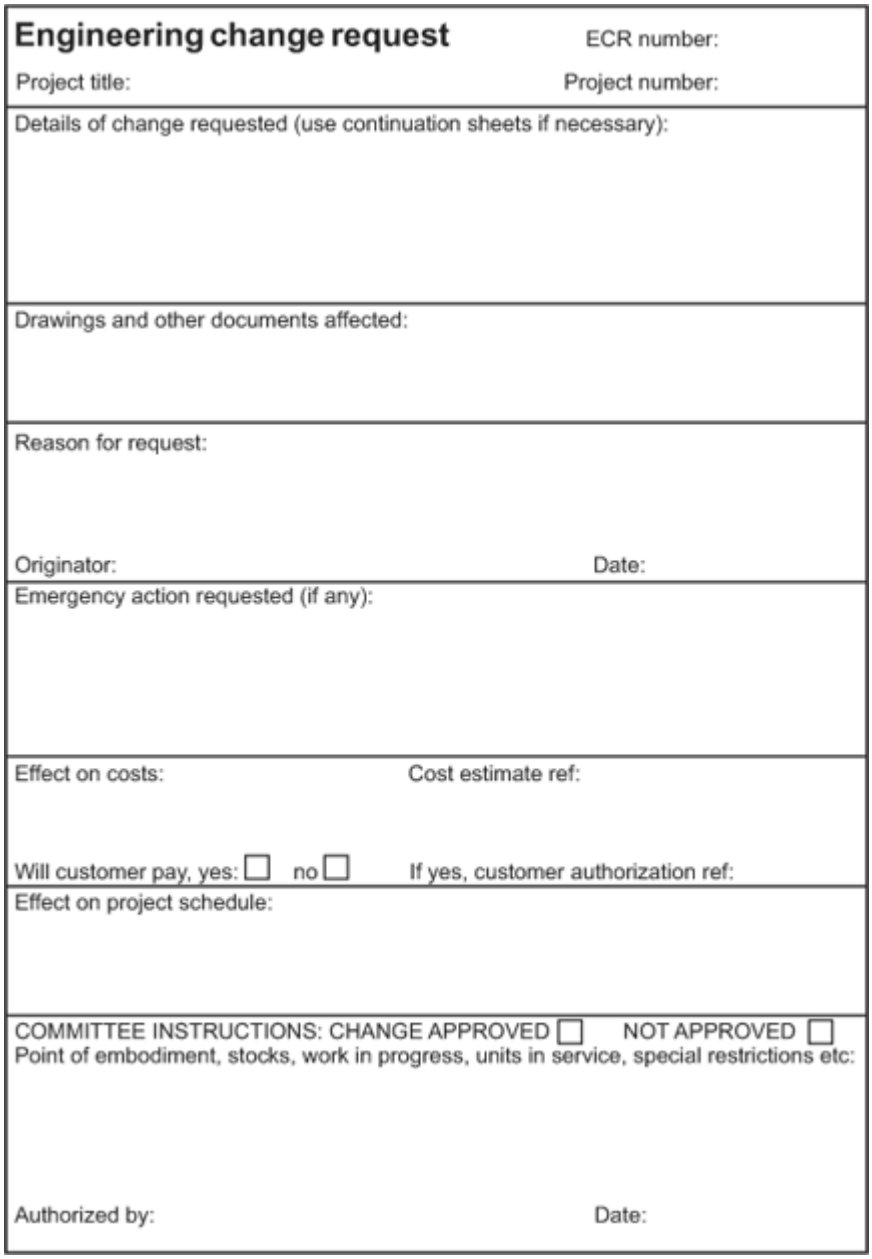

Engineering change request
ECR number:
Project title:
Project number:
Details of change requested (use continuation sheets if necessary):
Drawings and other documents affected:
Reason for request:
Originator:
Date:
Emergency action requested (if any):
Effect on costs:
Cost estimate ref:
Will customer pay, yes: ☐ no ☐
If yes, customer authorization ref:
Effect on project schedule:
COMMITTEE INSTRUCTIONS: CHANGE APPROVED ☐ NOT APPROVED ☐
Point of embodiment, stocks, work in progress, units in service, special restrictions etc:
Authorized by:
Date:

Figure 23.5 Engineering change request

Other requests for concessions might be for the use of alternative materials, different adhesives or acceptance of wider manufacturing tolerances. Any change from the instructions contained in drawings and specifications might represent a risk to performance, reliability, safety or interchangeability. As a general rule, therefore, concessions require the formal approval of the design authority.

Concessions (or production permits) usually fall into the classification of temporary changes. It is unlikely that the drawings will be updated to suit the

change, it being assumed that the manufacturing department will either be able to adhere to the original drawings in any future production, or will apply for a further concession.

Procedures for requesting concessions vary greatly from one company to another. They can range from the very informal 'Is it all right if we do it this way instead, George?' to a rigid discipline supervised by the quality control department. Rigid procedures might not be necessary in ground aviation projects but they must certainly be exercised in anything that will eventually get airborne. Figure 23.6 shows a suitable form.

The reasons for instituting a formal concession discipline are fairly obvious, because any departure from the instructions contained in issued drawings or specifications must be either disallowed or treated with a great deal of caution. Concession records may seem to have less significance than other project records once a project has been finished and put into service. But production permit and concession records are part of the project records which a contractor needs to keep in order to trace the possible causes of poor performance, faults or failures in equipment after delivery. If one of a number of identical units should fail in service, it is vital in projects to do with aircraft and aircraft components to be able to trace all other units containing the same concession in order to prevent further failures.

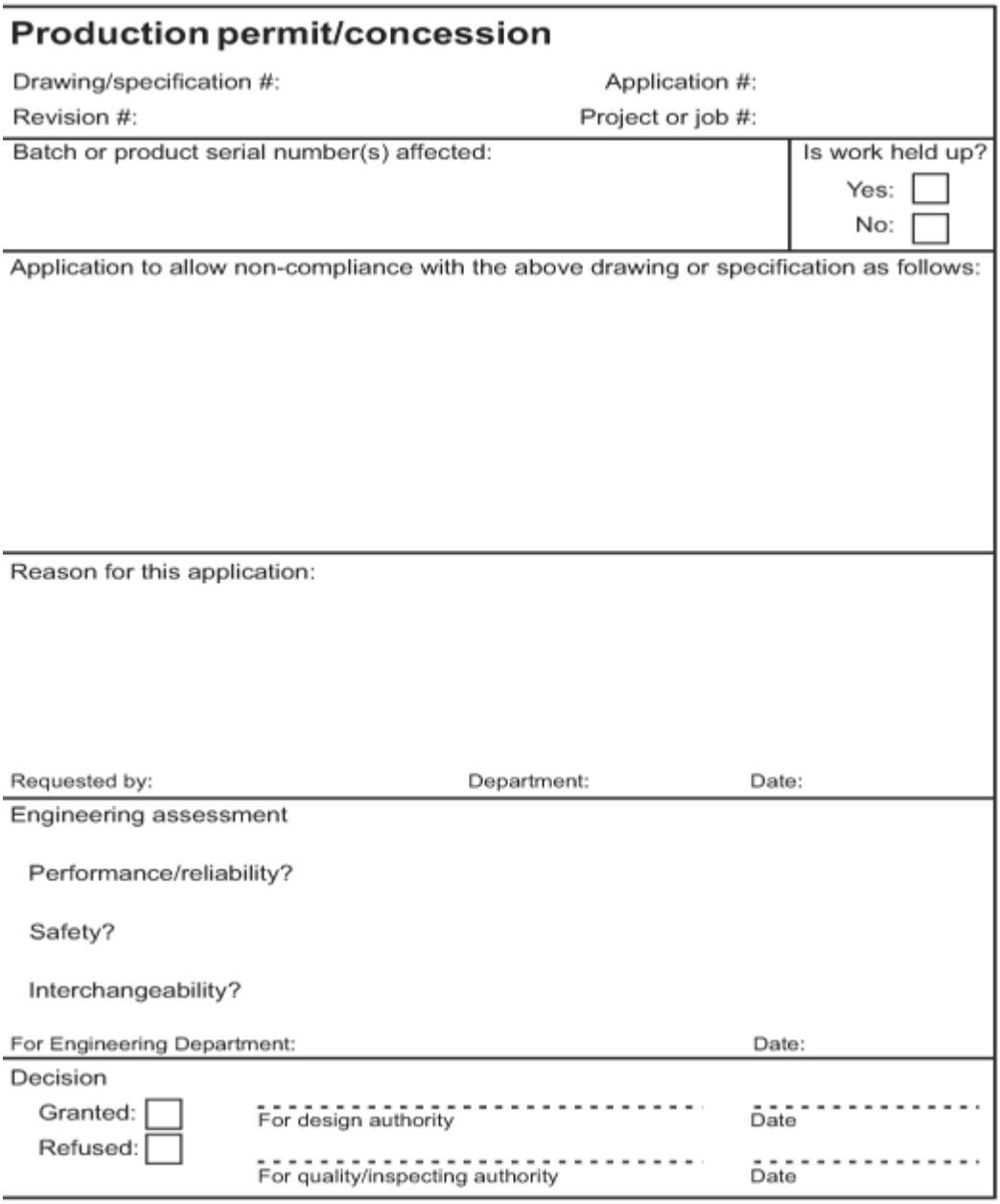
The procedures associated with the granting of concessions can exist in a variety of permutations and combinations of the methods described in this chapter. Whichever method a company decides to adopt, the concession register will be complementary to the manufacturing drawings, modification records, inspection and test records and build schedules in defining the exact composition of the completed project.

Engineering Query Notes

A feature of projects is that the manufacturing or construction drawings and specifications are usually completely new and untried. It is not surprising, therefore, that a higher incidence of problems in manufacture or construction is a characteristic of project work. These problems can range from design errors to difficulties in interpreting the drawing instructions. Design errors must, of course, be corrected by the reissue of amended drawings, for which the full-scale engineering change procedure will usually be invoked. Simple problems associated with the interpretation of drawings can be resolved by

an explanation on the spot from the appropriate engineer. Between these two extremes lies a no man's land of operational difficulties that are not a direct result of design errors, but which demand more than a simple explanation to get work on the move again.

In some firms any problems that cannot be resolved on the spot are channeled into a formalized 'engineering query' procedure, which relies on the use of forms similar to that shown in Figure 23.7. The general idea is that the plant supervisor who comes up against a problem explains the difficulty on one of these forms and submits it to the engineering department for investigation and reply. Naturally, this system can only operate effectively and be accepted if each query is afforded reasonably urgent consideration. The advantages provided by adopting this routine are that all queries can be registered and progressed by the change coordinating clerk to ensure that none is forgotten. Regrettably, one engineering director known to us preferred the formal system because it kept manufacturing plant personnel, together with their overalls, oil and grease, out of the nice clean engineering design offices.



Production permit/concession

Drawing/specification #: Application #:

Revision #: Project or job #:

Batch or product serial number(s) affected: Is work held up? Yes: ☐ No: ☐

Application to allow non-compliance with the above drawing or specification as follows:

Reason for this application:

Requested by: Department: Date:

Engineering assessment

Performance/reliability?

Safety?

Interchangeability?

For Engineering Department: Date:

Decision

Granted: ☐ Refused: ☐

For design authority Date

For quality/inspecting authority Date

[Figure 23.6 Production permit or concession]

Case example Suppose that a specified adhesive, when used according to the appropriate process specification, failed to produce the specified bond strength, so that when the unfortunate worker removed the clamps the carefully assembled work disintegrated into its constituent parts. The supervisor would need to ask the engineers what to do, and that could be done using an engineering query note.

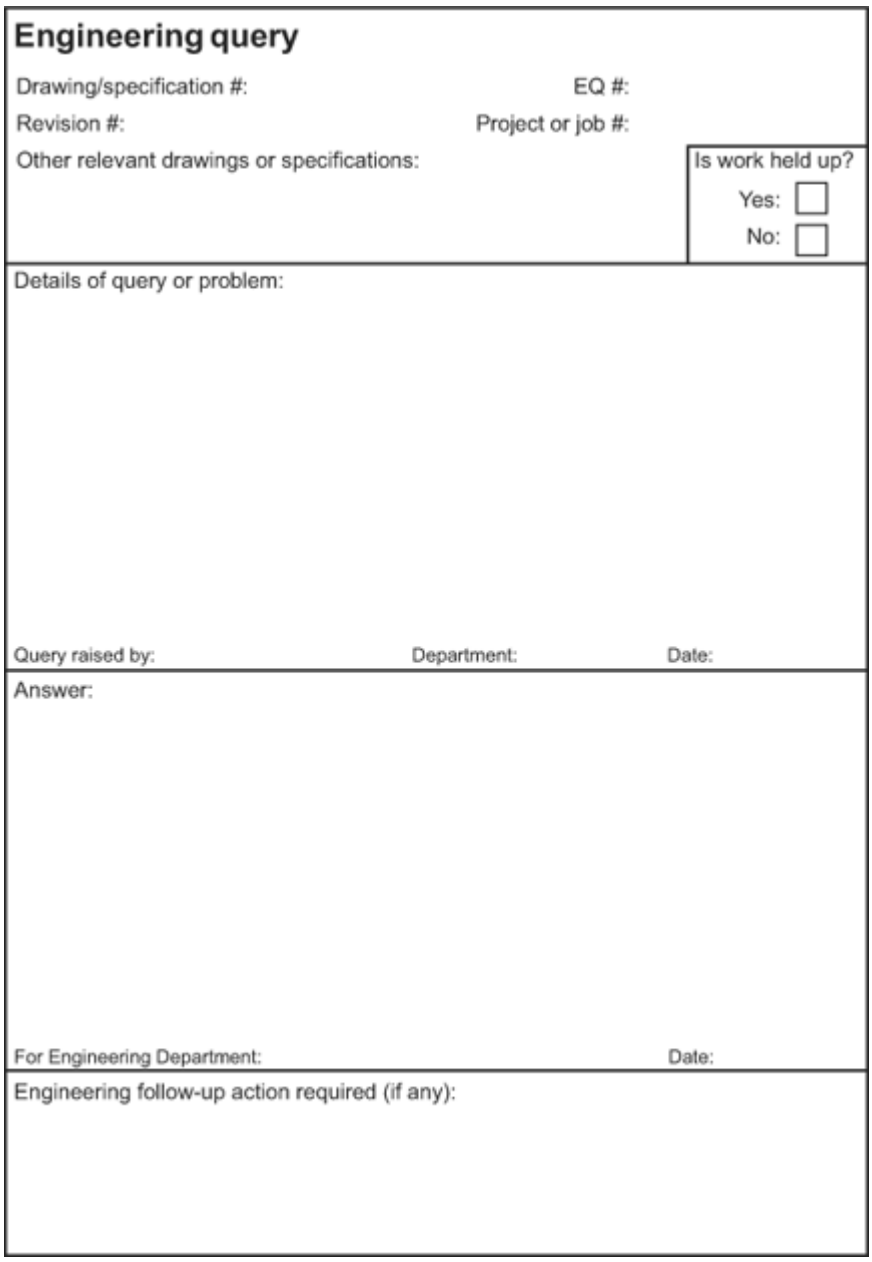


Figure 23.7 An engineering query form

If this problem proved too difficult to sort out on the spot, the engineers might be forced to return the query note with a temporary solution suggested. The instruction might read: 'Clean off adhesive, and use six equally-spaced pop rivets instead. Drawings will be modified and reissued.'

Conversion from engineering query to production permit If, as in the above example, an engineering query note is returned to a manufacturing plant department or assembly hangar with instructions that conflict with those

given in the manufacturing drawings, the query note becomes a document that carries authority to deviate from drawings. It has therefore become a concession or production permit.

Because engineering query notes are often converted into concessions in this way, companies that use them should consider combining the concession and engineering query systems into one procedure, with a single common-purpose form designed to cope with both needs.

Inspection Reports

Suppose that a block of extremely expensive raw material has been subjected to many hours of machining by highly skilled operators but, on final inspection, one of the measurements is found to be marginally outside the limits of tolerance. Too much material has been cut away; the error has resulted in the work being undersized and no rectification is possible. Any inspector would have to reject the job. In most companies the inspector would fill in an inspection report ticket or form, detailing the 'non-conformance'.

The relevant design engineers, if shown the inspection report, might decide that the error was too trivial to justify scrapping such an expensive workpiece. Perhaps it could still be used for the project or, alternatively, it might be possible to use it for a prototype assembly on the understanding that it must never be fitted into another assembly. A design engineer having the appropriate authority might feel able to annotate the inspection report accordingly, thus countermanding the inspector's rejection.

This is another method by which a job can be passed through an inspection stage, even though it does not conform to the issued drawings. The inspection report has been translated by the design authority into a concession or production permit.

VERSION CONTROL FOR MODIFIED DRAWINGS AND SPECIFICATIONS

One or two pitfalls can trap unwary project engineering staff into issuing drawings or specifications that are not what their revision numbers would make them seem to be.

Issue of Incorrect Versions

Diazo prints and translucent 'reproducibles' or 'sub-masters' are easily recognizable as copies and are thus unlikely to be confused with original documents. But with today's reprographic techniques and laser printers, copies of drawings are indistinguishable from their originals. Drawings produced from computer files can be printed at will on plain paper, so that more than one apparently original version of any drawing can easily exist.

Unless rigid safeguards are introduced, any designer can alter the design information in the computer and then cause a new 'original' to be produced without making the necessary change to the drawing or revision number. Unless there is a central drawings registry for the control and issue of drawings, there is no independent check to prevent such mistakes and measures must be devised to prevent the issue of drawings with incorrect revision numbers.

Case example One of us once asked a design engineer to produce some layouts of a large new design office. He began by measuring the accommodation area and producing an accurate drawing showing all the walls, doors, columns, windows and so on. He filed that drawing in his computer as a template, on which he overlaid all the subsequent electrical, lighting, partition and staff seating drawings. Every drawing that he produced still bore the original template number in its title box. Unfortunately that mistake was not realized until the local authority's planning inspector spotted it, to our acute embarrassment.

The Interchangeability Rule

The usual practice when a drawing is changed is to reissue it with a new revision number. If, however, a change results in a manufactured component or assembly being made different from other items with which it was previously interchangeable, it is not sufficient merely to change the drawing revision number. The drawing number itself (and therefore the part number) must also be changed.

This is a golden rule to which no exception should ever be allowed, whether the item is a small component or a big assembly.

Case example Suppose that a project requires the use of 1000 small spacers, and that after 500 had been produced in brass the design was cheapened to use mild steel. These spacers are truly interchangeable, and the part number need not be changed. But the drawing for the steel spacers would be given a new revision number.

Now suppose that the spacer design had been changed from aluminum to molded nylon because on some later manufactured assemblies it became necessary for the spacers to be electrically insulating. The old metal spacers can no longer be used on all assemblies. The metal and nylon spacers are not interchangeable. The drawing for the nylon version of these spacers must therefore be given a new drawing number.

EMERGENCY MODIFICATIONS

Project time is usually precious. If the need for an essential modification is discovered during the active production phase of a program there may simply be no time available to wait for the next change committee meeting. There are several right ways and at least one disastrously wrong way of dealing with this situation. Every organization can devise its own method, but we can end this chapter with examples of right and wrong methods.

Example of a Safe Emergency Change Procedure

If the need for a change is discovered that must be resolved quickly, the originator of the emergency change should ideally write out an engineering change request in the usual way and get it registered by the change coordinator. The change request must contain precise details of the change or be accompanied by a sketch, so that when the change is approved project work can resume with minimum delay and without having to wait for the original drawings to be corrected and reissued.

With this procedure, once the change originator has passed the request to the coordinator, it is the coordinator who becomes responsible for walking the change request through the system to get the change committee's approval. Under these circumstances it is usually sufficient to ask only the design authority (probably a chief engineer or the nominated deputy) to approve the change.

Even when project work has been resumed, the coordinator must continue to monitor the progress of the change to ensure that the relevant drawings and specifications are corrected and reissued. Thus even in the emergency, the formal change procedure has still been applied, but with accelerated progress.

Example of an Unsafe Emergency Change Procedure

Imagine the following scene. A prototype executive jet aircraft was nearing completion in its assembly hangar when one of the design engineers strolled through the hangar to admire the work. However, this engineer spotted a couple of fitters with worried looks on their faces. They were studying prints of the cockpit instrumentation panel assembly drawing, which they had laid out on a work bench.

This project was running seriously late, so any problems had to be sorted out quickly. 'What's up?' asked the engineer. The fitters explained that the two of the instruments could not be fitted because the holes cut for them in the instrument panel were too big. The design engineer could see that the instruments in the assembly kit were the right products, so clearly the original panel manufacturing drawing was in error by specifying instrument cut-outs that were too big. A temporary quick fix was needed, and the design engineer asked the fitters to get hold of some aluminum sheet to overlay the problem area of the instrument panel. Then holes of the correct diameter could be cut in the overlay.

The engineer made a rapid sketch of the panel overlay, with its reduced size holes, and gave that to the fitters so that they can make the patch part. To get this job past inspection, the engineer marked up the print of the panel assembly drawing to show the overlay pop riveted in place. The result was not pretty, but it allowed the instruments to be fitted and the engineer's authorizing signature on the marked-up print satisfied the inspector.

All this happed on a Friday afternoon. This engineer happened to be a keen rock climber who specialized in very severe climbs, solo, with minimal aids and protection. During the weekend a handhold comprising a small flake of rock detached itself from the mountain where this engineer was enjoying his leisure sport. That flake plunged 500 feet down a sheer face. Unfortunately, the engineer accompanied the flake on its descent and created a vacancy in the design department.

However, back at the plant everything was going well and the prototype was eventually finished. Test flights were successful and the first production batch of 12 aircraft was authorized. All the components were manufactured in batches of 12. When the first of these planes hit the assembly floor it was eventually discovered that there was a problem with fitting instruments to the cockpit instrument panel. The errors found on the prototype still remained because the instructions marked up on prints in the assembly hangar had not been communicated back to the design office, so the original drawings were not corrected. So 12 new instrument panels and, more to the point, the tooling from which they had been pressed, were all scrapped.

Marked-up prints are sometimes a necessary evil but when they are used it is essential that two sets of prints are marked up identically, one to be left with the manufacturing or assembly department and the other set to be taken back to the design office. Only that way can it be ensured that the original drawings will be corrected and brought into line with what the project needs.

24
Managing Project Costs

Cost management begins with budgets, and budgeting begins with cost estimating. Once the budgets have been evaluated, the process of cost management should be proactive and is the process of managing work and purchasing so that no budget is exceeded. That is the focus of this chapter.

Cost management is closely associated with cash flow management, which we deal with in Chapter 25. Then, in Chapter 26, we shall complete this trio of chapters that deal specifically with project cost issues by describing procedures that, although they are often confused with cost management, are strictly only methods for reporting and assessing money that has already been spent.

ESTABLISHING AND MAINTAINING PROJECT COST BUDGETS

There are several kinds of cost budgets but those which are of most interest to the project manager are job budgets (how much should each piece of work cost?) and departmental budgets (how much in total may each department or organizational group spend on this project?). Then each budget splits further into labor, materials and direct expenses.

There are clear and logical paths to the creation and maintenance of cost budgets. These are illustrated in Figure 24.1. Everything begins with project definition, which in turn leads to cost estimates and a WBS. In Chapter 5 we described how project cost estimates split into above-the-line items and below-the-line allowances. For the purposes of setting initial budgets, we should always use the above-the-line figures and retain the relevant below-the-line allowances as reserves.

There is a sensible rule accepted universally in project cost management, which is that project managers and other line managers should strictly be

held accountable only for direct costs. It is sensibly argued that these managers can have no personal control over indirect (overhead) costs because those are determined by the company's infrastructure, general operating costs and so on. So the costs depicted in Figure 24.1 are all direct costs.

Once the direct costs for a project have been estimated and the estimates have been approved, budgets can be developed from those estimates in at least two ways. Figure 24.1 shows that the estimates can be divided over the WBS to arrive at a budget for each task or job. Because the ideal WBS is constructed in strict hierarchical fashion, those individual task or job budgets can be rolled up to give the cost budgets for higher-level work packages until the prime cost of the project is reached at the apex. Prime cost is a convenient accountant's term for the sum of all direct costs. In Figure 24.1 we have chosen to call the value of the prime cost, excluding any provision for contingencies, $x.

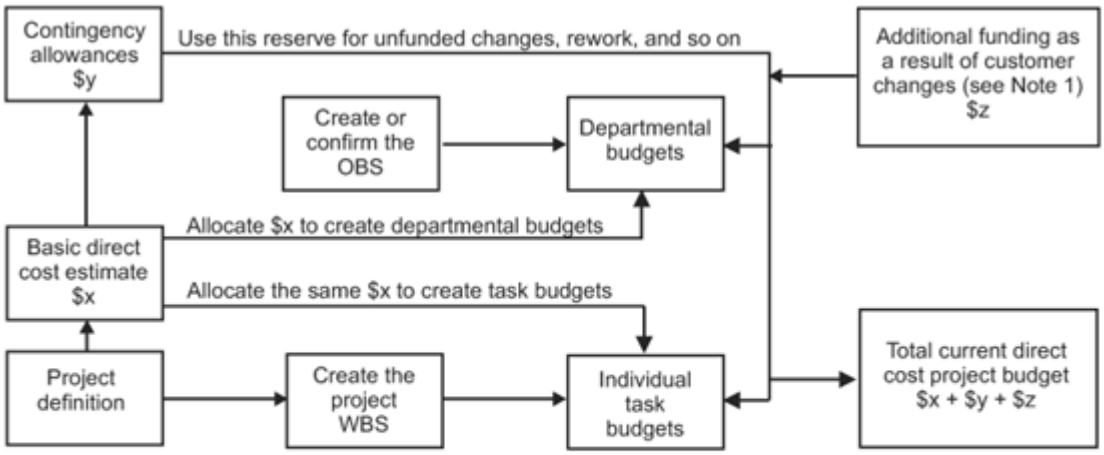

Contingency allowances $y
Use this reserve for unfunded changes, rework, and so on
Additional funding as a result of customer changes (see Note 1) $z
Create or confirm the OBS
Departmental budgets
Allocate $x to create departmental budgets
Basic direct cost estimate $x
Allocate the same $x to create task budgets
Project definition
Create the project WBS
Individual task budgets
Total current direct cost project budget $x + $y + $z
Notes:
1 Income $z cannot apply to R&D or internal management projects with no external customer.
2 For many projects an OBS will already exist in the form of the company's permanent organization.
3 All these budget items are for the direct costs of labor, materials and expenses. Overheads are accounted for separately and are not usually part of the budget for which the project manager and line managers are responsible.
4 Task budgets in the WBS can be for individual tasks, or they can be rolled up for larger work packages.

Figure 24.1 Derivation of direct cost budgets

The same $x amount can be divided up in a different pattern to distribute the prime cost over the OBS. That will result in a project budget for each department or group in the project organization.

A prudent housekeeper will set aside part of the household budget against a rainy day or unexpected calls on funds. So it is in project management, and

there should be a contingency fund available for every project. This is provided for in the original cost estimates by relevant below-the-line allowances, in particular the contingency allowance. In the example of Figure 24.1 we have called this contingency or reserve budget $y. Thus the absolute project budget is $(x + y) but at the start the authorized budget (or budget released for expenditure) is restricted to $x.

In the previous chapter on change management we explained how some changes have to be funded from within the organization. If the project manager is fortunate there will be sufficient money in the project's reserve budget to pay for them. As each unfunded change is approved and costed, a corresponding portion of the reserve fund is released (drawn down) and distributed over the relevant bits of the WBS and OBS. If the reserve budget of $y is allocated before all unfunded changes have occurred, then the project will be overspent.

In projects that are funded by external customers or clients, budget top-ups occur whenever the customer asks for a change and agrees to pay for it. That provides an additional pot of money which we have called $z in Figure 24.1. This is a variable sum which typically will grow throughout the project as the number of customer changes grows. In very large and complex projects this additional funding can be very significant. So in externally funded projects the total prime cost budget at any time can be expressed as the sum of the basic estimate, original contingency sums and extra amounts from customer changes. In the case in Figure 24.1 that amounts to $(x + y + z) where z is a variable that will probably increase through the project life cycle.

Part of contract administration is to ensure that as each reserve amount is drawn down, or as each new price increase from a customer change is received, all the relevant working budgets are kept up to date. This is a purely clerical function, but it demands accuracy and dedication. A project support office can be the ideal center for this bookkeeping job. Disputes between customers and project contractors can often be attributed to arguments over the correct final project price as affected by all the changes requested by the customer. So here is another case where dedicated documentation is very important.

PRINCIPLES OF COST CONTROL

Understanding the Main Elements of Project Costs

Cost control methods depend to a very large extent on the nature of the costs, so project managers have to know the different categories of costs they will have to deal with. Some of these issues were discussed in Chapter 4, in the context of cost estimating, and the definitions given in the beginning of Chapter 4 are relevant here. Figure 24.2 illustrates the main cost elements that make up the costs of a typical project. These split into two main groups, as follows:

1. **Direct costs**—costs that can be measured and associated directly with, and only with, a particular project task. Direct costs comprise the *variable costs* of a project because the rate at which they are incurred varies with the rate at which work is being performed.
2. **Indirect costs**—costs that with few exceptions constitute the company's overhead or fixed costs. 'Indirect' means that these are costs incurred generally in running the business, so that they cannot be directly associated with any one of several projects that might be in progress. Likewise, the term 'fixed' means that these costs will be incurred at a fixed rate, whatever happens in the project.

Figure 24.2 shows that the direct costs split into two additional sub-categories, namely:

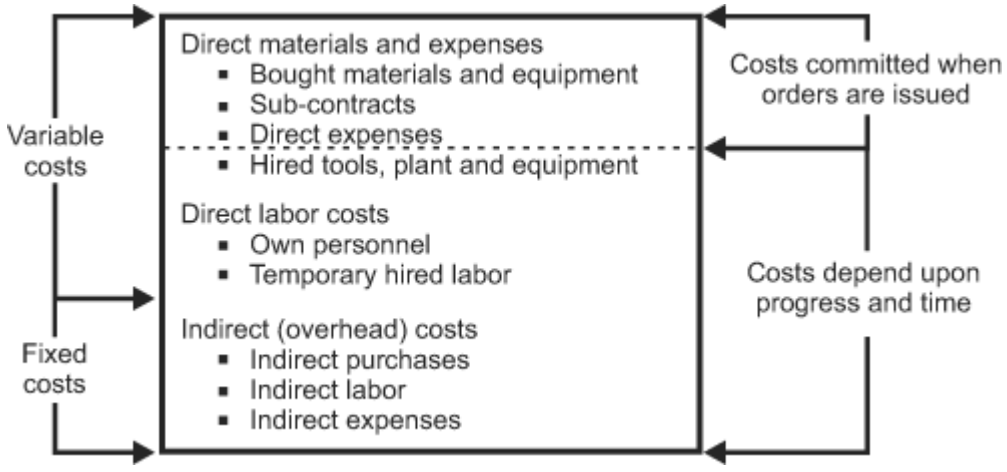


Figure 24.2 Cost elements in the context of controlling project costs

- the prices paid for direct materials, services and hired tools, plant and equipment;
- the direct labor costs (wages, salaries and other payments that contribute to the hourly or monthly cost of employing each person). These costs apply to all project staff on the payroll whose time can easily be allocated to discrete tasks. Thus a few senior managers and supervisors whose time cannot be charged to individual task cost codes might have to be classed as indirect staff whose costs are also indirect. Agency or other sub-contract staff brought in to work on project tasks can also be classed as direct labor if they are paid at a rate which depends on their recorded time.

There are gray areas in these classifications of direct and indirect costs and there are many differences between companies. One common example is the project manager's remuneration costs. The project manager's time is not usually attributable to single tasks within the WBS, so it is in that respect a fixed cost for the life of the project and indirect. However, this can easily be dealt with by having a task called 'project management' within the WBS and the project's overall direct budget. Then all the project manager's time and costs can be allocated to that single project task and this manager can be called a direct worker.

CONTROLLING DIRECT COSTS

Materials and Expenses

Materials and expenses constitute well over half the costs of most projects, and controlling their costs is thus particularly important. Cost control is exercised by following sensible purchasing procedures, as described in Chapters 19 and 20.

By far the most important act of cost control is exercised at the point of commitment, which means when the purchase order is issued or a contract is signed. Once a contract has been made with a supplier, the buyer's competitive advantage has gone and the seller has a monopoly when fixing the price of subsequent order amendments or cancellation costs. It is generally important to avoid purchase order amendments as far as possible, because these can push costs over budget.

The hire of plant and machinery is a special purchasing case because the cost of these items depends not only on the initial contract terms, but also upon the length of time for which the hire continues. To some extent these hirings combine the characteristics of both variable and fixed costs. Thus progress management is a principal factor in controlling hire costs. For example, suppose an outside contractor has installed scaffolding along the front of a hangar to allow other people to work safely at height on the hangar door suspension rails. The hire of that scaffolding will be per day or per week for as long as it remains on site. If work is stopped, for any reason, the scaffolding hire costs will continue to rise, through weekends and public holidays until the scaffolding can be dismantled and reclaimed by the contractor.

Direct Labor Costs

A job that finishes on time will generally incur only the budgeted labor costs. Obviously that depends on using only the amount of labor resources (people) intended and listed in the project resource schedules or work-to lists. Conversely, jobs that run late will probably overrun their budgets.

The exception here would be a job into which extra resources and overtime have been injected to accelerate a critical task to prevent it from running late. Although this job might then finish on time, it will incur additional costs as a direct result of the additional resources used. However, those additional costs will usually be more than compensated for by the time (and therefore fixed costs) saved for the whole project.

Thus good motivation of people and the control of progress are critical factors in controlling direct labor costs.

CONTROLLING FIXED COSTS AND OVERHEAD COST RECOVERY

Whatever the project, management must always strive to keep the fixed (indirect or overhead) costs as low as possible in relation to the variable (direct) costs, because high overheads can kill a company's chances of being competitive in the marketplace.

Project Manager's Influence on Fixed Costs

Most project managers work in premises or environments where they can have no substantive control over the organization's fixed costs. The project manager is not usually responsible for the periodic costs of accommodation, heat and light, sales and marketing, accounting, communications or the salaries and other expenses of general management.

However, as Figure 24.3 indicates, these fixed (overhead) costs are incurred by the organization every day, without fail, whether or not any work takes place on the project. A feature of fixed costs is that they continue to accrue, in the background, for as long as the project is active and taking up space and using the company's infrastructure services. Thus, if a project runs late, it will most likely use more indirect costs than expected or budgeted. The only significant control that the project manager can exercise over fixed costs is to make sure that the project will be finished in time.

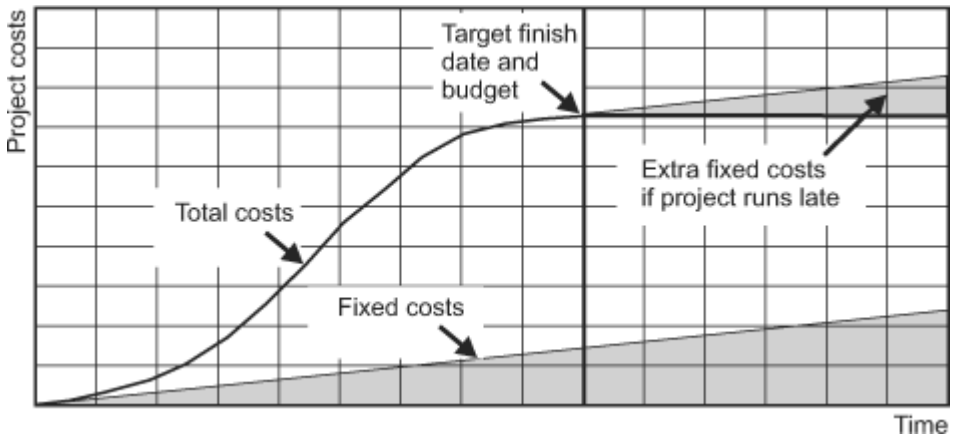


Figure 24.3 Typical project cost/time patterns and the impact of fixed costs

Cases where the project manager can exercise limited control over the rate of overhead expenditure The boundary between fixed costs and variable costs is not always precise. For example, overhead costs, although they are predominately fixed, often contain a variable element. Communications, printing and document copying are all activities which are often regarded as indirect or overheads, because they are costs incurred in running the business that cannot easily be identified with particular jobs. But these are variable costs, because they will increase or decrease with the

level of business activity. It is in this variable portion of the overhead costs where the easiest and quickest savings can be made by the project manager.

Some contracts allow the contractor to claim reimbursement of sundry expenses such as telephone calls, printing, photocopying and some clerical tasks from a project client or customer, provided that these activities can be identified directly with the project. This is often the case with professional organizations such as architects and legal partnerships. An attorney friend once told one of us that you can pick out an attorney on Main Street because he is the guy who helps an old lady across the road and then demands a fee when they are safely over.

In organizations carrying out several projects simultaneously it can be awkward to isolate the costs associated with one client or one project but the effort can be worthwhile. Although it is unlikely that the sums involved will be large compared with mainstream project activities, they are usually significant and worth recovering. Every expense that can be charged directly against a project should be so charged. Otherwise these expenses will simply inflate the general overhead costs, which must always be kept as low as possible if the contractor is to remain competitive in the market.

Suggested collection methods include:

- the use of a simple requisition system for all bulk photocopying and other reprographics services, with mandatory use of client or cost codes;
- mandatory use of cost codes on petty cash vouchers and all expense claims forms;
- the installation and proper day-to-day management of an automatic call logging system covering all telephone, and facsimile lines;

In one case from our experience this last measure reduced a company's total annual communications bill from $200 000 to $100 000 by preventing fraudulent use. Then half the remaining $100 000 calls were allocated to their projects, and the costs were recovered from clients. So, $150 000 was removed from the company's annual overhead account for very little expense and effort.

ADDITIONAL COST CONTROL FACTORS

Adherence to Cost Budgets

Taking the narrowest view, a project contractor should be concerned (for many obvious reasons) that the project is completed successfully without exceeding the planned costs (authorized budgets). In many cases, this is the only cost objective set for the project manager. Most of the conventional cost reporting and control procedures, including those described in this chapter, aim to achieve that objective.

In some cases (for example in internal management change and IT projects) budgets are the only cost consideration. There is no external customer and no profit to be safeguarded: simply the need to contain spending within the amounts previously authorized by the organization's senior management against the business plan.

Where there is a profit objective, it has to be remembered that profits are fragile and easily destroyed by overspending. When a company is operating in a highly competitive market, margins might have to be kept low. If the project is very keenly priced, say for a ten per cent profit, a budget overspend of only five per cent will halve that profit.

Contractor's Responsibility to the Customer or Project Owner

The contractor usually has some degree of responsibility for ensuring that the customer's cost objectives are also satisfied. The most obvious manifestation of this is the firm-price contract, in which the contractor's firm *price* is the customer's firm *cost*. Unless the customer rocks the boat by asking for changes, or the contractor goes bankrupt or is otherwise unable to finish the project successfully, the customer can plan its capital expenditure with confidence against a fixed budget.

In cost-plus projects, where the contractor is able to mark up costs and pass them on to the client with no fixed price limit, there is less incentive for the contractor to limit costs. In fact, the converse can be true: the greater the amount spent, the greater will be the 'plus' or profit element. A long-running cost-plus service contract or an ill-defined reimbursable-cost project can be regarded as a gravy train. Then the contractor has an ethical, but difficult, duty to ensure that:

- only legitimate costs are claimed;

- work is carried out as efficiently as if the contractor were spending its own money.

Where large capital investments are involved, such as in airport development or expansion projects, the managing contractor's project manager can have a specific cost management duty to the client, which broadens the cost objective further. The project cost management function then extends to predicting and reporting costs to the client, working with the client to help schedule and control expenditure and marshal the necessary funds.

THE TOTAL COST APPROACH

The total cost approach is a way of regarding costs holistically, solving logistical problems or otherwise planning to achieve the lowest overall cost. This approach can be used in a wide variety of situations. It has been used, for example, in distribution logistics where decisions have to be made about the location of warehouses and designation of transport methods so as to achieve the lowest possible total distribution costs of retail goods.

Total Costs in Project Management

In the context of project management, total cost considerations mean that managers in the project organization work together, each considering unselfishly how the work contribution of their department is likely to affect the costs incurred by other departments. One example is where a suggested change in design approach, although resulting in greater design difficulties and costs, might save considerable time and money in the resulting production or construction methods. The total cost approach can, therefore, mean increasing the planned expenditure in one department in order to generate greater cost savings in the rest of the organization.

Example One of us was once privileged, in the role of planning consultant, to witness a convincing demonstration of the total cost approach in action. The scene was a project-planning meeting in the engineering director's office of a company in Illinois. The company was about to start three new projects, each for the design and manufacture of special purpose equipment for external customers. The engineering director was in the chair. Also present at

the meeting were the chief engineer and other senior engineers, and (significantly) the manufacturing manager and his senior production engineers.

Various design proposals were passed back and forwards between the design engineers and the production people and, one by one, design approaches were agreed that would lead to the lowest total company cost, while maintaining high quality standards. A high level of enthusiasm, motivation and cooperation was generated from the start.

The three projects, planned with multi-project resource allocation and given effective project management, were all subsequently completed on or before time and well below their originally budgeted costs (that is, below the total cost levels previously experienced by the company for comparable projects).

Involving the Customer

The true total cost approach should extend to include the costs to be incurred by the customer after the project has been handed over. These are the costs of operating and maintaining the installed equipment or plant. The customer might have to be convinced of the contractor's good intentions, because a higher initial cost might be needed as a justifiable investment in reducing the total life cost.

Example This principle is well known to the Illinois company mentioned above, who widened their total cost approach to involve their customers in continuous design, quality and cost discussions.

In a typical project development, the concept and design of special manufacturing equipment to be supplied under each project contract was discussed in detail with the customer's own design engineers. Solutions were developed that resulted in the best combined design for the supplied equipment and the customer's own application for that equipment. The customer's product design was thus influenced by the designers of the machine that would manufacture it. The supplier of the equipment enjoyed a fair profit, and the customer benefited from reduced costs of the components that it manufactured with the supplied equipment.

This process is called integrated engineering or simultaneous engineering. It strives not only to keep project costs to a minimum but also to achieve the

customer's performance and quality requirements at lowest total cost when using the supplied equipment in its own operations. This clearly benefits both the project organization and the customer.

This approach has clear implications for the aviation industry in many areas. Whether the project is for airport operations or for the manufacture and supply of aircraft, the project company will always do better if it works with the customer to achieve the outcome that is of most benefit to both parties. In aviation projects that consideration should also extend to the paying passengers, although obviously they will not be able to take an active part in simultaneously engineering the project.

A CHECKLIST OF COST MANAGEMENT FACTORS

- Cost awareness by those responsible for design and engineering, preferably involving a 'total cost' approach.
- Cost awareness by all other project participants throughout the life of the project.
- A project work breakdown into work packages of manageable size.
- A code of accounts system that is aligned with the work breakdown coding structure.
- Cost budgets, divided so that each part of the WBS is given its own share of the total budget.
- A separate division of the total cost budget by the OBS so that line managers know the portion of the total project budget for which they are individually responsible.
- A cost accounting system that can collect and analyze costs as they are incurred and allocate them with minimum delay to their relevant cost codes.
- A practicable work schedule.
- Effective management of well-motivated staff, to ensure that progress meets or beats the work schedule.
- Purchasing methods that recognize the importance of getting expenditure right when each purchase contract is made—not afterwards when it is too late.
- Effective use of competitive tendering for all purchases and sub-contractors to ensure the lowest costs commensurate with quality and to

avoid committing costs that would exceed budgets.

- Restricting unfunded changes to those that are essential for reliability and safety.
- Appropriate control of customer-requested changes so that justifiable price increases are achieved.
- A method for comparing expenditure with that planned for the work actually done.
- Supervision and quality control of all activities that gets things right first time.
- Proper drafting of specifications and contracts.
- Discreet investigation to ensure that the project customer is of sound financial standing, with sufficient funds available to make all contracted payments.
- Similar investigation, not necessarily so discreet, of all significant suppliers and sub-contractors new to the project company's experience.
- Avoidance of unbudgeted day works by sub-contractors on construction contracts.
- Where day works are unavoidable, proper authorization and retention of day works sheets.
- Strict control of payments to suppliers and sub-contractors, to ensure that all invoices and claims for progress payments are neither overpaid nor paid too soon.
- Recovery from customers of all incidental expenses allowed for in the contract charging structure.
- Proper invoicing to the customer, especially ensuring that claims for progress payments or cost reimbursement are made at the appropriate times and at the correct levels, so that disputes do not justify the customer in delaying payments.
- Effective credit control, to expedite overdue payments from the customer.
- Occasional and random internal security audits, to detect losses through theft or fraud.
- Effective and regular cost/progress reports to senior management, highlighting potential schedule or budget overruns in time for corrective action to be taken.

That long list indicates the complexity of cost management, and we do not claim that the list is complete.

TRANSACTIONS IN FOREIGN CURRENCIES

The currency units used in cost estimates, budgets, cost reports and in other project documents are obviously important. For projects conducted entirely within the borders of one country there should be no problem, and the national currency is the natural choice for all budgeting and reporting purposes. If the project is to use imported services or materials, the logical method for expressing both the budget and the expenditure is to convert all sums into the 'home' currency, being careful to state the exchange rate used in each case.

When a project involves working for a foreign client, the contractor may be obliged by the terms of the contract or the agreed project procedures to prepare budgets and report all expenditure in the currency of the client's country, or in some other international currency (such as Euros or English pounds). The currency chosen may then have to become the control currency for the project.

COST COLLECTION METHODS

It can be assumed that every established company will have procedures in place for collecting, analyzing and recording project costs. It is important that this analysis and reporting, of both incurred and committed costs, is carried out promptly. If the figures are a month or more old when they reach the project manager, what chance does he or she have of taking action in time to reverse any bad trend?

Most of the procedures for collecting costs and allocating them to the project cost codes are the responsibility of the company's cost accountants but cooperation from the project manager and other operational managers is usually essential to prevent delays and mistakes.

Collecting the Costs of Bought-in Materials and Equipment

It can be assumed that the organization's purchasing, accounting and stores procedures will ensure that the costs of materials and bought-in equipment are always collected and recorded. The routine cost accounting systems would normally cover costs associated with the payment of invoices, and the later job costs when materials are issued from stores for manufacturing jobs. The three options are as follows:

1. The dates when orders are placed (the committed costs). This is the earliest possible time for monitoring the costs of materials and the most useful for assessing performance against budget.
2. The dates when invoices from the suppliers of goods and services are due to be paid (the actual costs).
3. Particularly for manufacturing projects, job costing that depends on the evaluation of stores requisitions (when the materials are withdrawn from stores for use on the project). That can often be after the suppliers' invoices have been paid.

Figure 24.4 is a graphical representation of these three different methods, each of which has its own advantages and disadvantages. All the curves have one thing in common. Each has been drawn by adding together the materials expenditure on a month-by-month basis as soon as the data are known. The main difference between these curves is the information route through which the cost data have been obtained.

Cost data from committed purchase costs Whenever the project is of the kind where equipment, materials or sub-contracts are ordered specifically for use on the project, the project manager should be concerned particularly to see that a system is in place for recording and tabulating the values of purchase orders as they are placed. This information, at the time of commitment, will give the earliest possible indication of cost trends against the budget (see curve (A) of Figure 24.4. It is unlikely that the purchasing organization or the company's cost accounting procedures will be set up to record committed costs in this way, and cooperation between the project manager and the purchasing organization is essential if this valuable form of communication is to be established and maintained.

Any items already available from general stocks, and which are not to be ordered specially for the project, must of course be allowed for and included

in the total commitment. This is easily accomplished: all that is necessary is to withdraw these stocks from general stock and pre-allocate them by transfer into the project stores. The requisitions used to withdraw these materials from production stores can be costed at their standard cost, and the costs added to the total project commitment.

Cost data from stores issues Curve (B) in Figure 24.4 is the only graph which could be derived in all circumstances, whether stock or project purchasing had been adopted. In this case, the materials costs have been found by valuing all the items listed on stores requisitions or similar paperwork (usually at standard cost) as the items were withdrawn from stores for use on the project. This method is particularly applicable to manufacturing projects.

Errors can arise owing to discrepancies between the amounts listed and the amounts actually issued or used. Valuations can also be inaccurate if outdated standard costs have been applied. These errors ought not to be significant, however, unless there are serious shortcomings in the stores or costing administration. The real disadvantage of this most usual form of costing only becomes apparent when the results are compared with those obtained from alternative methods. It is not called 'historic costing' for nothing. The project manager would have to wait until after the materials had actually been used before any under- or overspending trend became apparent. Thus the data obtained from this method will be of no help in controlling project costs.

Cost data from suppliers' invoices Payments made against suppliers' invoices provide the most accurate account of purchased materials costs for a contract. Project purchasing is an essential condition, otherwise all invoices cannot easily be related to the project being costed. Curve (C) in Figure 24.4 shows how this kind of cost information might build up as the project progresses.

Note that Curve (C) lags behind both the other two curves by an appreciable period. Most invoices will be paid only after the goods have been received or, in many cases, after they have actually been built into the project.

The significant fact which emerges here is that information derived from suppliers' invoices is far too late to be of any use whatsoever in budgetary

control. By the time the facts are known, the money has long since been committed and nothing can be done. This emphasizes the importance of measuring and controlling project purchase costs at the point of commitment, which means when the purchase orders are issued.

Comparative accuracy Before leaving Figure 24.4, observe that all three curves attain different final levels. In this example the differences have been exaggerated deliberately, and in practice no more than about five per cent of the total material costs should separate the highest and lowest asymptotes.

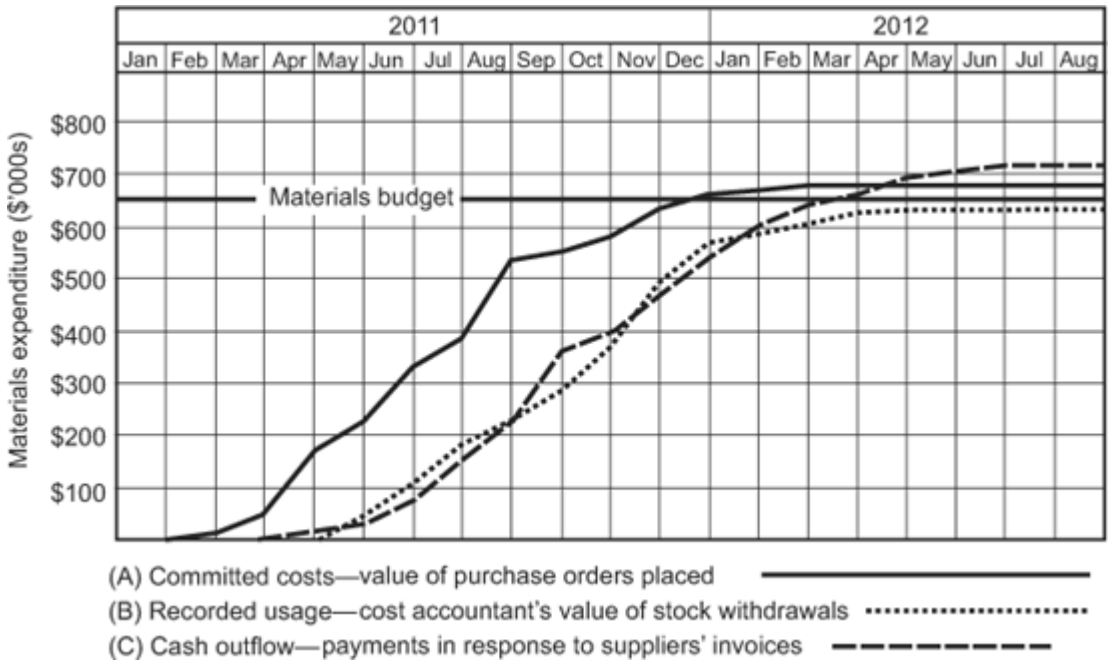


Figure 24.4 Three ways of recording the cost of project materials

The curve of committed costs (Curve (A)), did not quite reach the true final cost value (Curve (C)) owing to slight differences between suppliers' quotations (the amounts shown on the purchase orders and used to compile Curve A) and the final prices actually invoiced. These extra costs arose because one or two purchase orders were placed after the suppliers' quotations were time-expired, and because of incidental expenses, such as freight, packing, insurance, and port and customs duties that were not originally taken into account.

Curve (B) (materials actually withdrawn from project stores) also fell slightly short of the real total as shown by Curve (C). This could imply that

some over-ordering took place (leaving some goods in stock at the end of the project). Changes to the scope or specification of the project during its execution might also have led to materials being left unused in stores. When surpluses are accumulated in this way these should really be written off as a charge against project profits, unless they can be returned to the suppliers for full credit or used elsewhere on other projects. Otherwise the surplus materials will only have to be written off at a later date.

Collecting Labor Costs

It is often argued, with justification, that managers should only be held accountable for labor budgets under their control in terms of labor-hours and not labor costs. This argument is based on the reasonable assumption that these managers cannot be held accountable for increases in the employment costs of labor throughout a project life cycle. For example, they often take no part in wage negotiations, particularly where these are influenced or controlled by national industry agreements. But these managers can be held accountable for the labor-hours worked on each job.

General timesheets A common method for recording and collecting the time spent on projects by professional and other direct office staff on projects is to ask each individual to complete timesheets at regular intervals. Timesheets are usually compiled weekly and require each person to enter the time spent against each relevant cost code or job number, probably expressed to the nearest half-hour. An example of a weekly timesheet is shown in Figure 24.5.

An important part of the timesheet procedure is that the person's supervisor should check and verify the entries before adding an approval signature.

Whatever the method used for collecting labor costs, the time records should be as accurate as possible. If the project is organized as a team, so that everyone works on the project all the time, the only errors to be expected would be in allocations to sub-codes within the project. If, however, the organization is a matrix, people might be working on more that one project during a week, or even on the same day, and the apportionment of time between projects becomes more subjective and open to error or abuse.

Staff often have times when they work less efficiently or actually waste time, and there is always a risk that such time will be booked wrongly to the

most convenient number available. People should be encouraged to fill in the entries on their timesheets every day. If this chore is left until collection of timesheets at the end of the week, mistakes will inevitably be made as individuals strive in vain to remember what they were doing earlier in the week.

Timesheet

For accounts department use only

Name: _____ Staff number: _____

Department: For week ending:

Job number	Sat'day	Sunday	Monday		Tuesday		Wednesday		Thursday		Friday	
			Normal	O'time	Normal	O'time	Normal	O'time	Normal	O'time	Normal	O'time

Enter times to nearest half-hour. For holidays use 0096 sickness 0097; special leave 0098; waiting time 0099

Signature: _____ Approved: _____

Figure 24.5 A weekly time sheet

Timesheet errors on firm-price contracts can throw up false profit and loss assessments and reduce the value of historical cost records for future analysis and comparative cost estimating. In cost-plus contracts, timesheet mistakes will result in billing errors to the customer, which could be at best unethical and, at worst, fraudulent.

Timesheets should, therefore, only be signed as approved by those nominated as being authorized to do so. It may be necessary introduce a higher-level check by arranging for a suitable independent person to carry out an occasional timesheet audit. In cost-plus contracts the customers will probably insist on some such safeguard.

Timesheets for agency staff Staff supplied by external agencies to work in the contractor's offices will be provided with their own agency timesheets, which the project contractor is expected to sign to show that the company agrees with the hours for which the temporary employee will be paid by the agency, and which will eventually appear on the agencies' invoices. These timesheets are rarely suitable as project cost records, and it will probably be necessary to ask the agency staff also to fill in the contractor's own timesheets (which can be color-coded if required to distinguish them from the timesheets used by permanent staff).

The time spent by agency staff working in agency offices will usually be charged for weekly, supported by detailed timesheets from the agency. The contractor may wish to specify and supply the timesheets that are to be used. Checking and correct authorization are obviously important, and the contractor may decide to arrange random, unannounced inspection visits to the external office as a precaution against fraud.

Direct input of timesheet data to the computer The more powerful project management software systems, when networked, allow staff to key in their timesheet data directly. This procedure can save considerable time but the following must be borne in mind:

- checking, auditing and approval are more difficult to arrange and errors can be expected;
- the system will not work unless everyone is clear about the cost codes to be used;
- there will be additional system costs, which can be considerable and might even be a multiple of the number of staff who will enter data.

Dayworks Sheets for Casual Work from Sub-contractors

A common method for dealing with miscellaneous work carried out by sub-contractors depends on the use of dayworks sheets. Some such sub-contractors submit their bills infrequently, or only after very long delays. It can prove very difficult trying to reconcile invoices received six months or even longer after the work has been done, especially since dayworks sheets tend to be scrappy tear-offs from duplicate pads. Even longer delays between the work dates and receipt of final invoices have been known.

One instance concerned a project for various external and internal improvements to an office building in central London. In addition to the work specified in the original fixed-price contract, there were numerous incidental costs, such as miscellaneous plant rentals, the provision of rubbish skips, rental charges for a site hut, sundry materials and many other small additional tasks carried out at the request of the office occupier. All of these extra costs were recorded as they were incurred on hundreds of dayworks sheets, each signed by the office manager. In today's values the total project costs exceeded £1m, much of which was attributable to the dayworks. The project lasted many months and the construction company, well known and respected in the City of London, submitted its invoice almost a year late. There was no dishonesty, but the lapse of time made the invoice extremely difficult to check and approve. The services of an independent quantity surveyor were required, at extra cost, before the invoice could be reconciled and passed for payment.

It is important that any company employing contractors or sub-contractors checks, approves and retains copies of all dayworks sheets until the relevant invoices have been received and cleared for payment.

AUDITS AND FRAUD PREVENTION MEASURES

The need for timesheet entries to be checked and approved by managers and supervisors has already been mentioned. This is, in effect, a form of auditing. It helps to protect the client of a cost-plus project from being overcharged. Incidentally, it also helps to ensure that archived records of fixed-price projects will be relatively free from errors, and therefore of more use when making comparative estimates for future projects.

Any company must always be aware of the possible risks when any manager or other member of staff has authority to commit expenditure or authorize payments on its behalf. Even where complete trust exists between senior management and their subordinates, the procedures should be audited and, where necessary amended, to reduce the possibility of fraud.

A company should set financial limits above which any manager must seek superior approval before authorizing any particular item of expenditure (for example, a purchase requisition).

Payment of suppliers' invoices should be authorized by a responsible person who is not the same person who signed the associated purchase orders. That will provide an independent check and reduce any temptation for buyers to order goods or services for their own use. All of us who have held senior responsibility for dealing with suppliers and sub-contractors will have at times received suggestions of favors that, if accepted, would amount to fraud. One of us, for example, was about to depart for a few days' leave when he was asked by a sub-contractor, 'Are you going somewhere nice?' 'No,' was our answer, 'I shall be replacing the roofing sheets on our veranda.' 'You don't need to do that,' said the sub-contractor, 'We can easily send over a few men to do that little job for you.' We know of far more valuable offers which, had they been accepted, would clearly have been fraudulent.

Rules should be laid down as to the levels of hospitality or gifts that those with purchasing authority may accept from suppliers and sub-contractors. These rules should be drafted carefully so that they do not destroy normal goodwill and accepted moderate practices, but instead deter managers from receiving pecuniary benefits that might tend to corrupt, distort judgment or generate feelings of obligation to one source of supply.

Petty cash vouchers for expenses and sundry purchases are open to misuse. We remember a case where a highly regarded member of a purchasing department regularly arranged for small purchases of sundry stationery items verbally, claiming reimbursement each time against petty cash vouchers. That saved the greater expense of the formal purchase order system and all would have been well if she had not made a common practice of adding items to each petty cash claim voucher for fictitious purchases that were not on the original requisitions and were never received by the company. Thousands of dollars could have been saved if a procedures audit had been carried out earlier.

CONCLUSION

This chapter has described some of the measures needed to establish a project budgeting and cost recording system, as a preliminary step towards implementing effective cost management. We have emphasized that cost management, although requiring cost collection and analysis, is essentially a proactive role for project managers, their subordinates and other managers.

The next chapter deals with the related and important subject of cash flow management. After that, in Chapter 26, we shall conclude this trio of cost management chapters by describing methods which attempt to evaluate and report project cost performance.

25
Managing Project Cash Flows

Consider and imagine. You are a brilliant aircraft designer. Your employer is receiving a steady trickle of orders for a new two-seater light aircraft. You, in the meantime and in your private residence have just invented a revolutionary wing design that would give tremendous lift and minimum turbulence, yet be simple and relatively inexpensive to manufacture. You know that, with this invention and your genius, you could design a two-seater light aircraft that would sell at a fraction of the price of the planes manufactured by your employer. So should you consider giving up your day job and going into business on your own?

Of course you would have many issues to resolve, not least with the regulatory authorities. But you have close friends in high places and can foresee only smooth progress to gaining acceptance and approval for your ideas, designs and completed aircraft. Profitability is not an issue because you know your innovative design would cheapen manufacturing and assembly costs, so that you could expect to make a huge profit on every plane sold. But you earn only $150 000 a year and have no realizable assets of any significant value that you could sell. You simply do not have the cash up front with which to start your venture. In project management terms, you have a cash flow problem.

Cash flow management is very similar to managing your own checking account and budgeting your own day-to-day finances. Without money in the form of ready cash you cannot do all the things that you would like to do in your life. So it is with all companies. Even when the work or services they provide are potentially profitable (which means that the project or product costs less than the expected revenue from sales) if there is no cash in the bank to meet the immediate costs of running the business and paying the staff, suppliers and sub-contractors, that business will fail. *Cash is the lifeblood of projects.*

In this chapter we deal with cash flows from the perspective of the project manager, so that we are concerned here only with the direct costs (because the project manager has no direct control over the organization's fixed overhead costs).

UNDERSTANDING CASH FLOWS

Project managers tend to occupy their minds with day-to-day matters such as technical difficulties, design errors, the allocation of work, progress against the schedule, performance of sub-contractors and expenditure against the authorized cost budgets. The vital subject of project cash flow might be appreciated by a few of the senior staff who work in project organizations, but it is more often completely misunderstood by people whose qualifications and interests are mainly technical. Two very common mistakes are:

1. confusing cash outflow schedules with net cash flow schedules;
2. regarding a predicted final project profit and loss statement as being completely satisfactory if it forecasts a good end result, but without giving any thought to the cash flows that must take place during the project life cycle.

Cash flow forecasting was introduced in Chapter 6 in the context of financial project appraisal. That was very early in the project life cycle, when project investments and possible cash returns were being considered to support (or condemn) the business case. This chapter revisits cash flow scheduling much later in the project life cycle. Now the requirements for project scope and deliverables are well established. There is a coded WBS, a detailed critical path diagram, resource schedules with work-to lists, and a computer system all in use or ready to go. What the project manager (or the vice president of finance) now needs to know is:

1. How much have we got in the bank to start with? (The opening balance or cash reserves.)
2. How much is this project expected to cost each month? (In other words, what are the expected cash outflows?)

3. How much money is expected to flow into the bank each month? (The cash inflows.)
4. Will our balance at the bank remain healthy or is there a risk of being overdrawn? (Too much debt could result in serious liquidity problems.)
5. If there is an unauthorized overdraft risk, how can we plan in advance to work round that?

Main contractors and other managers of large capital projects are sometimes asked to predict cash flows as a service to their clients. Customers need to know when to expect claims for payment from the contractor. In some projects customers buy equipment for the project themselves, or at least pay the suppliers' invoices directly and, again, they need to be advised in advance of the likely amounts and timings of these commitments. So project cash flow schedules can serve a dual purpose, helping both the contractor and the customer to make the necessary funds available to keep the project afloat and financially viable.

Basic Terminology

Projects with external customers The following explanations refer to projects that have an external client or customer. In these projects it would of course be expected that the client or customer would pay an agreed price or otherwise reimburse the costs of the project according to the contract terms.

Cash outflows are all items of direct expenditure needed to carry out the project. They include labor costs, payments made to suppliers and sub-contractors, payments of professional fees, special insurance premiums, licensing costs, interest on loans, loan repayment installments, the costs of travel and subsistence and every other conceivable item of expense directly caused by conducting the project.

Cash inflows are deposits of cash into the bank or cash reserves from any source during the life of the project. The principal source of these must be payments from the customer or client. Where bank loans are agreed in advance to cover periods when the accounts would otherwise be overdrawn, the loan amounts count as cash inflows.

Internally funded projects, such as R&D programs and management change projects Where there is no external customer or client to fund a

project, all the cash inflows must come from bank loans, existing reserves or calls upon shareholders. If the project organization is part of a larger group of companies, it sometimes happens that some or all of the cash inflows can be sourced from group funds. Scheduling cash for internal projects can be complex, so we expand on this topic in the following section.

CASH FLOWS FOR INTERNALLY FUNDED PROJECTS

Cash flow patterns depend, among other things, upon the nature of the project. Cash flows for projects sold to external clients or customers are usually all wrapped up when the project is delivered and the customer makes the final payment against the contract price.

Cash flows for internal projects, such as business change and IT projects are more complex. These projects usually require considerable expenditure during the fulfillment phases of their life cycles, but they will not earn any financial return until some time after their completion. The same applies to R&D projects for the design and development of new products, which must wait for successful sales of the new product before investment in the development project can be repaid. The common factor among all these projects is that they are internally funded, which means that no external customer or client is there to pay for the project work while it is actually taking place.

Thus the cash flows for internally funded projects are principally *outflows*, which means that all expenditure must come from cash in hand, financial reserves, loans or some other source. The cash *inflows* or project benefits (if any) will not usually be realized until some time after the initial project has been finished. It can take as long as 20 years for the costs of an aircraft design and development project to be recovered from aircraft sales. Thus, whilst managing day-to-day work during the active part of the project life cycle, the project manager usually needs only to schedule the cash outflows for these internally funded projects. The cash inflows are benefits to be realized much later. Those benefits can be used to fund future internal projects.

METHODS FOR SCHEDULING CASH FLOWS

Like so many other things in project management, cash flow scheduling is a matter for common sense and establishing a logical sequence of steps to arrive at the required schedule. These steps are described below and illustrated in the summary diagram in Figure 25.1.

Scheduling Cash Outflows

The cash flow scheduling process begins with a WBS that has cost estimates for all its constituent parts. The cost estimate needs to show the costs of labor and materials separately, because labor costs cause immediate outflows when wages and salaries are paid, but bought items and services only have to be paid for somewhat later, when the invoices arrive from the suppliers and sub-contractors. So the cash outflow schedule depends partly on knowing the detailed cost estimates or budgets for labor and materials.

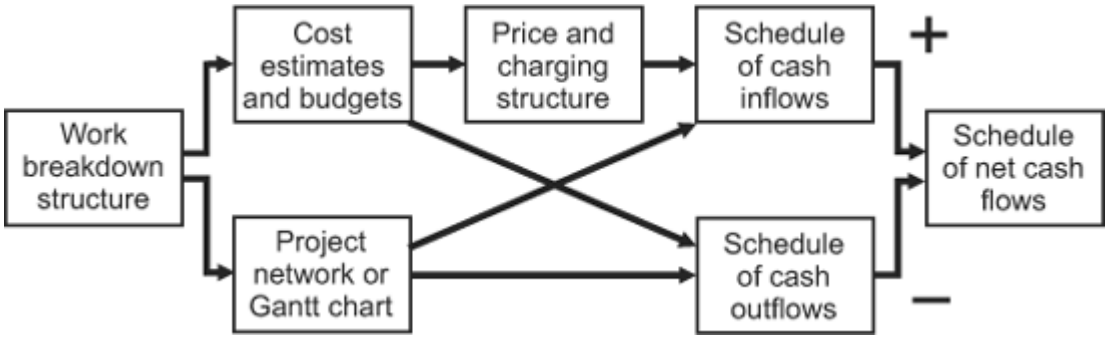


Figure 25.1 Essential elements of a project net cash flow schedule

Given detailed cost estimates and a practicable project plan, the scheduling of project cash outflows becomes fairly straightforward arithmetic. However, it is very important to set each item of expected expenditure in the period when the payment will actually become due. For example, the cash outflow for purchasing an item of equipment or a bulk supply of materials takes place not when the purchase order is placed (the time of cost commitment) but at the time when the invoice will actually be paid. Of course the act of committing the project to any new cost is important, but that comes within the context of *cost* control (described in Chapter 24) and not *cash* control.

Projects often have other expenses beyond labor and materials. For example, if some of the funding is from loans, then loan repayments and

interest payments on outstanding loan balances will have to be included in the cash outflow schedule.

Scheduling Cash Inflows

The project manager will need to know for each inflow event both the size of the inflow and its expected timing. Inflows from loans or group funds can be predicted by the accountants, on whom the project manager must rely for this information. Inflows from an external customer will depend on the terms of contract. Most contracts for large projects allow for a series of stage payments that often begin with an initial down payment or deposit when the contract is signed. From this information, the project manager should be able to determine the amount of each predicted inflow. Stage payments will generally depend on one of the following two conditions:

1. An identifiable milestone has been reached in the project progress, which will allow the project company to make a claim on the customer for an agreed installment of the project price.
2. At regular intervals (usually monthly) progress on the project is assessed and quantified in financial terms, and the project company is able to make a directly associated claim for a progress payment from the customer. For construction projects it is usual for such claims to be certified by an independent authority such as a quantity surveyor, who will visit the site to ensure that each claim truly reflects the amount of work done during the claim period. For software such as IT or engineering design, an independent consultant or engineer is often engaged to perform this progress assessment and certification role.

Sometimes stage payments from customers allow only for the reimbursement of costs, and are intended solely to help the contractor to maintain a healthy cash balance. Then the profit element is deferred for payment until at or near the end of the project, in the final payments from the customer. Contracts will often allow for part of the final payment to be deferred for (say) six months, so that it will only be paid when the customer has had a chance to ensure that the project performs according to its specification and that all snags have been sorted out.

Scheduling Periodic Net Cash Flows

In each accounting period, the sum of all the cash inflows during the period minus the sum of all the outflows for the same period gives the net cash flow for the period.

Scheduling Cumulative Cash Flows

The cash flow schedule is completed when all the elements are added together from left to right along each row to produce cumulative amounts in spreadsheet fashion. This will be illustrated in the following case example.

From the cash flow management point of view, it is the cumulative amounts in the bottom row that are critical. These indicate the expected cash balance in hand at the end of each scheduled period. Clearly if the amount goes negative at any time, the accountants will need to make some provision with the bank or other funding source.

CASE EXAMPLE: SCHEDULING CASH FLOWS FOR THE LOXYLENE AVIATION FUEL PROJECT

The subject of this case is the design and build of a petro-chemical plant that will refine a mix of mineral oil and vegetable oils to produce a new aviation fuel to be called Loxylene. This fuel will be characterized by its low carbon emissions and relatively high exothermic energy output. It will thus be an efficient fuel because it will increase the range of existing planes with no need for serious modification, whilst being kinder to the environment than its competitors.

This project has many stakeholders, from the investors who sponsor the Lox Chemical Company Inc (the eventual manufacturers of Loxylene) through the main contractor that will build the refinery, to the airlines that will use this fuel in their planes. Many of these stakeholders (such as some of the major suppliers of equipment and sub-contractors) will need to schedule their own cash flows because each of these different companies will in effect be performing its own sub-project of the Loxylene refinery project.

We shall concentrate here on the project as it is viewed by the main contractor, but we shall conclude this case by commenting on the very different cash flow of this project as it will be experienced by the Lox

Chemical Company. The main contractor is Projects Unlimited Inc, and the project organization is a contract matrix of the form that was described in Chapter 8 and illustrated in Figure 8.8.

Scheduling the Cash Flows of the Main Contractor

Projects Unlimited Inc (PUI) is the main contractor, and its cash flow schedule sheet for this project is shown in Figure 25.2. Note that all cash figures in this schedule represent $10 000 per unit (for example, 100 in the schedule represents $1m).

To produce this schedule, PUI had to go through many of the steps already described in these pages, such as producing a WBS, cost estimates and a detailed working schedule. The cash flow schedule shown here is a summary that rolls up many far more detailed items through the WBS. Preparing a cash flow schedule on this scale is a big task, but made easier if appropriate software is used and all the WBS items are hierarchically coded.

The principal cash inflows for this project will come from the customer (Lox Chemical Company) and the contract terms allow for stage payments that will limit PUI's exposure to debt. In other words, the customer will fund some of the work in progress. These predicted payments from the customer are tabulated in the cash inflows section of Figure 25.2. Of course if the project does not advance according to schedule, these stage payments could be delayed because PUI will only be able to invoice them to Lox Chemical Company against independently assessed certificates that verify the amount of progress claimed.

Projects of this kind usually run into a cumulative negative net cash balance before final payments are received from the customer, and that is the case here. However, this cash flow schedule is for this project only, and it is only part of the total cash flow picture of PUI when all its other concurrent projects are considered. So PUI has cash flows from those other projects in and out of its bank, and it also has substantial reserves saved from previous profitable projects. As things stand at the beginning of the project, these other reserves and sources of income would be more than sufficient to finance a temporary cash shortfall on the Loxylene project of up to $10m. So it is only when the predicted cumulative cash flow for this project would threaten to exceed $10m that the company would need to approach its bank for a temporary short-term loan. PUI does have a good loan arrangement with its

bank and we can assume that the interest rate is two per cent per annum on the balance outstanding.

Tracing the schedule through all its quarterly periods, it is clear that PUI's debt from this project would exceed its own self-imposed limit of $10m by the first quarter of 2012 if the vice-president of finance took no action. Accordingly the firm has availed itself of the line of credit provided by the bank and has drawn down a loan of $4m (which is shown correctly in this project's inflows). From then on interest payments have to be allowed for, but PUI expects to clear this loan in two installments of $2m each, in the second quarter of 2013 and third quarter of 2014.

The total cost for designing and constructing this project appears to be $115.38m, but this includes the $4m temporary bank loan which balances this amount in the inflows. So the true project cost (which must include the bank interest payments) is predicted to be $111.38. The predicted cumulative inflow is $9.91m, which appears to be a modest profit prediction of less than 10 per cent. However, the project terms of payment allow for the customer to retain ten per cent of the total price for six months after project handover, and this amount is beyond the timescale of our schedule and could not be shown in the inflows. So the total predicted profit target should be nearer 20 per cent, unless the project runs into serious overspending or late delivery.

PROJECTS UNLIMITED INC	Loxylene aviation fuel refinery for Lox Chemical Company																	Project number P21900 Issue date September 2010
Item	Quarterly periods - all figures $10,000s																	Total budget
	2011				2012				2013				2014				2015	
Cash inflows	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	
Bank loans					400													400
Client's payments	50	30	50	100	200	500	1000	1000	1100	1500	1000	1000	1500	1500	1000	800	800	13130
Total cash inflows	50	30	50	100	600	500	1000	1000	1100	1500	1000	1000	1500	1500	1000	800	800	13530
Cash outflows																		
Engineering	14	25	59	80	85	63	43	23	12	11	9	6	7	10	14	14	10	475
Purchasing		5	45	5	500	310	745	295	750	665	615	850	1242	1576	750	470	10	6832
Construction				17	35	97	245	393	436	654	382	241	186	45	30	30	15	2761
Loan interest						2	2	2	2	2	1	1	1	1	1			400
Loan repayments										200					200			400
Total cash outflows	14	30	104	102	620	472	1035	713	1200	1532	1007	1098	1436	1632	995	514	35	11538
Net cash flows																		
Periodic	36	0	(54)	(2)	(20)	28	(35)	287	(100)	(32)	(7)	(98)	64	(132)	5	286	765	
Cumulative	36	36	(18)	(20)	(40)	(12)	(47)	240	140	108	101	3	67	(65)	(60)	226	991	991

Figure 25.2 Net cash flow schedule for the main contractor of an aviation fuel refinery construction project

Scheduling the Cash Flows of the Project Owner

The owner of this Loxylene project is, of course, the Lox Chemical Company. That company, too, will have its own cash flow concerns and can be expected to produce its own net cash flow schedule. We need not show that schedule here, because it will be constructed in similar fashion to that produced by the main contractor and it will use similar methods. However, the timing will be considerably different because pretty well all the outflows must take place before this project can begin to earn income from the production of Loxylene.

So the Lox Chemicals Company must see this as an internal management project, with the benefits to come (as with most management projects) only when the project begins to make the product. Aircraft manufacturing companies experience similarly delayed benefits to their cash flows, with all the project benefits accruing far later when the products begin to sell. As we described in Chapter 6, projects where the cash flows are predicted to take place several years in the future should be analyzed using discounted cash flow methods.

USING PROJECT MANAGEMENT SOFTWARE TO SCHEDULE CASH FLOWS

Cash is a replenishable project resource. As such, it can be scheduled by the same software, at the same time and using the same basic methods as the project resource scheduling described in previous chapters. Computer systems with these capabilities have been in existence since the large mainframe machines of the 1960s and one of us was scheduling resources and cash outflows successfully for multiple projects as early as the 1970s.

Cash flow scheduling using resource scheduling techniques can save considerable time and effort, but requires considerable expertise, ingenuity and experience, not to mention a particular kind of aptitude. Willingness to resort to a few tricks and some manual intervention will usually be necessary because the capability of critical path-based resource scheduling will never stretch to cover every possible item of cash outflow. Inflows are even more difficult to accommodate.

All of this presupposes that the organization is carrying out project resource scheduling by computer. Unfortunately far too many do not and the

subject is covered very poorly in the literature.

Scheduling Labor Costs

Project management computer programs usually allow a unit cost rate to be specified for each resource, and will also allow the planner the alternative option of stating an estimated cost for a whole activity (particularly useful for materials costs and other expenses). The resulting schedules are very valuable because they set out the predicted project costs (cash outflows) against the project timescale after all tasks have been scheduled as work-to lists, which will generally agree with the levels of each resource that are available for project work.

It is possible, in the best programs, to specify not only the standard cost rate, per hour or day, for each type of resource, but also to specify the higher rates payable for threshold resources. Threshold resources are those brought in from emergency availability levels (such as overtime or temporary agency staff) to carry out critical tasks that cannot be performed without overloading the resources normally available.

Costs for unspecified tasks The computer schedule will include costs only for direct labor, and then only for the tasks that can be defined and entered in the network diagram. It will recognize neither any of the 'sludge' activities mentioned in Chapter 16 (tasks or absences that prevent staff from working on the project yet still cost money) nor the indirect (overhead) costs of the project. Manual intervention will usually be needed to add in correcting amounts (as a percentage) for these omissions. However, with skill, this procedure becomes entirely practicable. Our own experiences in this field typically produced total cash outflow schedules that were within five per cent of those made by the cost estimating engineers, but with the important advantage that our costs were scheduled against time.

Scheduling Cash Outflows for Materials and other Purchases

The estimated costs of materials and equipment can be scheduled by placing budget costs on the relevant purchasing activities on the network, and then allowing the computer to produce timed expenditure schedules. This will usually require the addition of activities to the network for the sole purpose

of cost scheduling. Figure 25.3 is a network fragment that illustrates this method.

Each activity in Figure 25.3 represents a task connected with the purchase of an item of equipment or some project materials. Suppose that this purchase task is for a bulk load of materials, to be shipped to the project manufacturing plant as one load at a total delivered cost of $5000. The planner can place this estimated cost on activity 1040, 'pay the supplier', to ensure that the computer will schedule this cost correctly as a cash outflow at the appropriate time. The duration of activity 1040 might be zero, in project terms, but some computers do not feel happy about assigning cost to activities with zero duration. So, in practice, the duration would probably be estimated as one day. Note that this is not the same as assigning a cost rate for a replenishable resource. Instead, it is a quite different process of assigning a cost to the whole activity.

Much later in the project, when work is actually taking place and orders for materials are being placed, the project manager will need to know the level of costs committed (rather than actually spent) at any given time as part of cost control. The same cost of $5000 for this load of raw materials could be added on to activity 1025, which would then place the expenditure at the time of commitment rather than as an actual cash outflow.

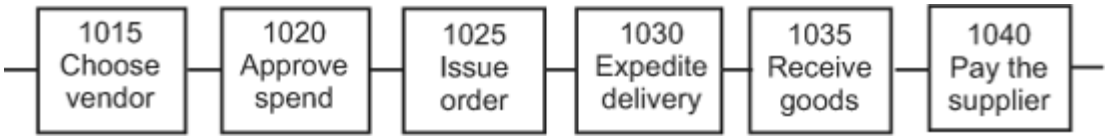


Figure 25.3 Network detail needed to schedule purchase commitments and cash outflows
This network fragment illustrates the level of detail needed if the computer is going to schedule costs and cash. Placing all the purchase cost on activity 1025 will schedule the costs as a contractual commitment, whilst placing all the same cost on activity 1040 will schedule the cash outflow.

Those among you who have followed this argument so far will now be asking: if this $5000 cost is shown on two different activities in the network, how can we prevent $5000 for this purchase from being charged twice to the project in all the cost reports? The answer is to give all the commitment activities one department sort code, and give all the cash outflow activities a different department sort code. Now the computer can be asked to filter and report costs against each of these different codes, thus producing one

schedule for the forecast committed costs and another for the expected cash outflows.

These are just some of the ways in which project management software can be tweaked to report cash outflows and cost commitments. Anyone with sufficient ingenuity will soon learn to devise others.

Using the Computer to Schedule Cash Inflows

The procedure for scheduling cash inflows is very similar to that for scheduling the outflows associated with purchases.

The planner must first identify those tasks in the project that, when finished, will trigger revenue for the project. By far the most common of these are tasks that can be associated with the progress or stage payments specified in the project contract. The most important of these milestones will usually be the start activity of the network and the finish activity at the end of the project. However, in a typical project there will usually be several intermediate progress payments or other cash inflows.

The cash inflow scheduling process requires that there is a task in the network for every foreseeable case where a cash inflow should occur. Each of these tasks is then designated as a project milestone. It is best to create tasks especially for the purpose, rather than identify the completion of tasks with long durations as the trigger events. All this is easily achieved by inserting special milestone activities at the appropriate places in the network, each with a duration of one day, and each being given the relevant cash inflow value as its estimated total task cost.

All except really useless project management software can produce reports containing only milestones. Thus the computer can be arranged to schedule expected cash inflows.

CONCLUSION

When familiarity is gained with the use of a particular computer system, and with the allocation and use of filtering, sorting and reporting codes, the above methods can be combined to allow the preparation of schedules and graphs for both committed costs and cash outflows.

Planners who become familiar with a particular scheduling program will learn how to exploit its features to produce the schedules they need. They will, for instance, be able to solve the more complex problem of scheduling the expected timing of stage payments for capital equipment purchases and sub-contracts so that these will be properly included in the total project cash outflow schedule. There must be at least one suitable activity in the network that can be identified with every case when a cash flow incident is expected to happen.

The capabilities and methods of use vary greatly between different computer systems, and there is usually more than one way to achieve a desired result even within one project management program. Even when a program appears not to possess the required capability, there are often 'tricks' that can be employed to produce the output needed.

Scheduling *net* cash flows from project resource schedules is, however, a far more difficult problem, if not impossible. Manual intervention will probably be needed. But solving all these problems can be an enjoyable and creative pastime, far more productive and rewarding than solving Sudoku puzzles.

26
Reporting Progress and Costs

This chapter continues the subject of cost management by describing techniques that can evaluate performance against budgets, analyze trends and attempt to predict the total final project costs. The tools described are important ingredients of cost management because they can provide information in time for corrective action to be taken. However none of the methods described in this chapter will do anything to control costs unless the project manager acts on the information gained. Indeed, procedures for reporting and analyzing project costs actually add costs to the project themselves, and they usually do not add value.

MILESTONE ANALYSIS

Milestone analysis is one of the simpler methods which managers can use throughout the project life cycle to compare the actual costs and progress experienced with the costs and progress planned. The method is less effective and less detailed than others described later in this chapter, but it has the merit of needing a relatively modest amount of management effort to set up and maintain. It also requires less sophisticated cost accounting than other methods and can be used when project schedules are not particularly detailed.

Perhaps the best way to demonstrate the benefits of milestone analysis would be to begin by considering what happens when actual costs are compared against cost budgets when there are no milestones or other relevant information about the progress achieved.

Cost Monitoring without Milestones

Figure 26.1 shows the kinds of curves that might result if total project costs are recorded regularly and plotted on a graph against time. These curves

usually have a characteristic S shape and are widely known as S-curves. These graphs convey little information in their early days unless they are compared with budgets. So one practice is to draw a graph of a project's expected costs on the same axes as the actual cost curve, to produce a time-scaled project budget.

The time-scaled budget in Figure 26.1 is represented by the dotted curve. This curve was plotted by combining information from the cost estimates and the project plan, so that the estimated costs for all work packages are included in the curve at their scheduled times. The project manager should, therefore, be able to consult the graph at any time during the execution of the project to find the amount of total project costs that should have been reached if all is going to plan.

In the absence of a suitable work breakdown with budgets it would not, of course, be possible to draw a time-scaled budget curve. In that case, the best that could be done would be to draw the budget as a straight line joining two points, starting from zero cost at the graph's origin and reaching the total estimated cost at the planned completion date. That approach can be dismissed as being of no use whatsoever.

The actual cumulative project costs can be plotted at suitable intervals on the same axes as the time-scaled budget. If the costing system is at all reasonable, it will be possible to plot these costs fairly accurately. This has been done in Figure 26.1, where it can be seen that actual costs have been recorded up to the end of week 28.

Interpreting the Result Where There are no Milestones

Graphs that attempt to compare actual costs with the time-scaled budget, even when they are plotted with great care, are of very limited management use as they stand. The missing piece of information in Figure 26.1 is the corresponding progress or achievement.

At one extreme, if no money is being spent at all, then it is a fair assumption that no progress is being made either. It is also true and easily understood that a significantly low rate of expenditure usually indicates an inadequate rate of progress and achievement. Unfortunately, some managers then proceed to make the less acceptable assumption that if expenditure is being incurred at the planned rate, then progress and achievement must also

be either on plan or ‘about right’. This is a very rough and ready guide that can lead to dangerously wrong conclusions.

Suppose that the project illustrated in Figure 26.1 has been running for 32 weeks, when the planned expenditure should then be $500 000. There are people who would be well satisfied on being told that the reported expenditure is at or just below $500 000. But those people fail to ask all the vital questions which should be considered by any project manager, namely:

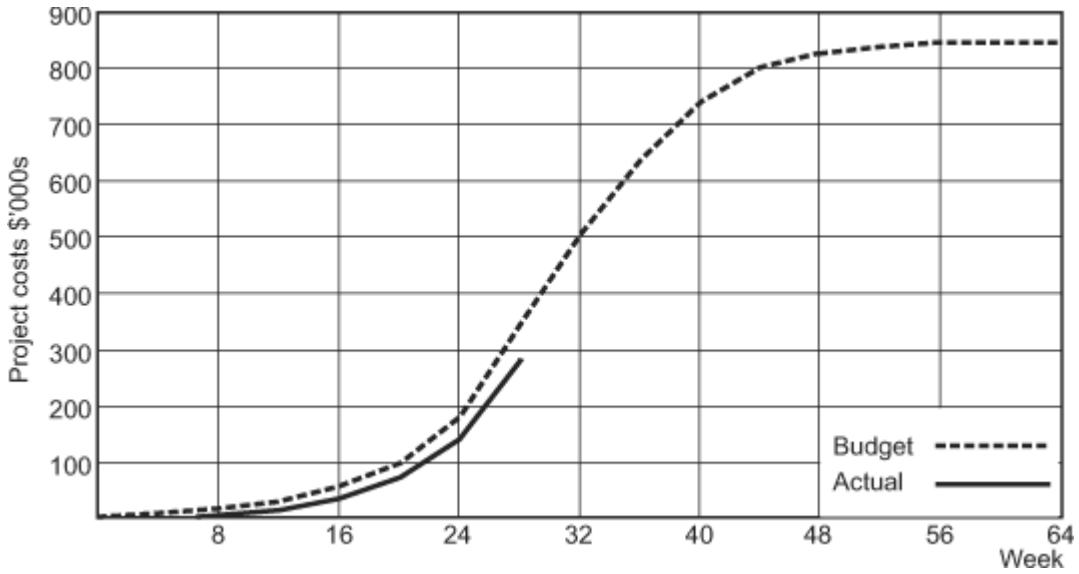


Figure 26.1 Comparison of actual costs against a time-scaled budget
Comparisons like this mean little unless the corresponding achievement is measured.

1. How much have we spent to date?
2. What should we have spent to date?
3. What have we achieved so far?
4. What should we have achieved by this time?
5. What are the final cost and delivery prospects for the project if our performance continues at the current level?

Milestone monitoring can help to answer these questions.

Explanation of the Milestone Method

Identifying milestones The first requirement in milestone analysis is to understand what is meant by a milestone. A milestone denotes a particular,

easily identifiable stage in the progress of a project towards completion. It might be acceptance by the customer of a final design concept or layout drawing, the issue of a package of drawings for work to begin, the day when a building is made watertight so that internal trades can start, the date when electrical power is first switched on to a new installation, or any other such occasion. In aviation projects milestones occur when approvals are received from regulatory authorities, when a prototype aircraft first begins to be assembled, when a plane makes its first test flight, when the first production plane is delivered to a customer and so on. Of course, the most important milestones of all are the two which mark the beginning and the end of a project.

Milestones have particular significance in projects carried out for paying clients, where the contract allows for stage or progress payments to the contractor. The achievement of each milestone usually triggers one of these payments.

All good project management software allows the user to designate appropriate tasks as milestones. Each milestone is then achieved when the relevant milestone activity is reported as finished. This becomes a little complicated when a true project milestone depends on completion of more than one task, where no single task on the network can be identified as the milestone. Precedence notation, however, is very adaptable and it is easy to solve this problem by creating a milestone event artificially wherever that is required. All that is necessary is to insert milestone tasks with zero or unit duration at the appropriate network intersections. Each of these milestones can be declared complete when all its preceding tasks have been accomplished.

Milestone analysis starts, therefore, by choosing and naming the achievements that can most effectively be used as project milestones. Milestones should coincide with the completion of packages from the WBS.

Plotting the budget/milestone plan For each milestone, two pieces of data are required. These are:

1. the date on which the milestone is scheduled to be achieved;
2. the estimated cost or budget for the associated work package (that is, the expected cost of all the work needed to achieve the milestone).

When all milestone data are available the milestone/budget curve can be plotted. This process starts by sketching the time-scaled budget curve. The position of each point is determined by matching the cumulative cost estimates for the project work packages against the planned achievement dates for those work packages. It might be necessary to use all the constituent tasks, rather than complete work packages, to produce sufficient points on the graph. Care must be taken to ensure that no estimated costs are left out, so that the budget curve will reach the cost estimated for the project. So far this is similar to the process used to produce the time-scaled budget curve in Figure 26.1.

To complete the budget/milestone graph, symbols must be added to the budget curve to represent all the milestones. Each milestone must be positioned on the budget curve at the date scheduled for its completion.

Plotting the graph of actual expenditure and milestone achievement To be able to plot the graph of actual expenditure for comparison against the plan, two further items of information must be collected:

1. the date on which each milestone was actually achieved;
2. the project costs actually incurred (including committed costs of purchased items) at the end of each cost monitoring period.

It must therefore be assumed that a procedure exists for recording the total costs actually incurred for the project at suitable intervals. To these costs must be added the costs committed for the purchase of relevant materials and equipment (the value of purchase orders placed). The intervals between measurement dates might be weekly or monthly, and will depend to some extent on the life cycle time for the project.

The actual costs can be plotted as a graph on the same axes as the time-scaled budget. Points on the graph should be highlighted by symbols that indicate the actual completion date for each milestone. To be able to compare the planned and actual graphs sensibly, it helps enormously if all the milestones can be given simple numbers. If the milestones marked on the budget curve are, for example, numbered 1, 2, 3, 4 and so on, the corresponding points on the actual cost graph can carry the same numbers to make comparison easy.

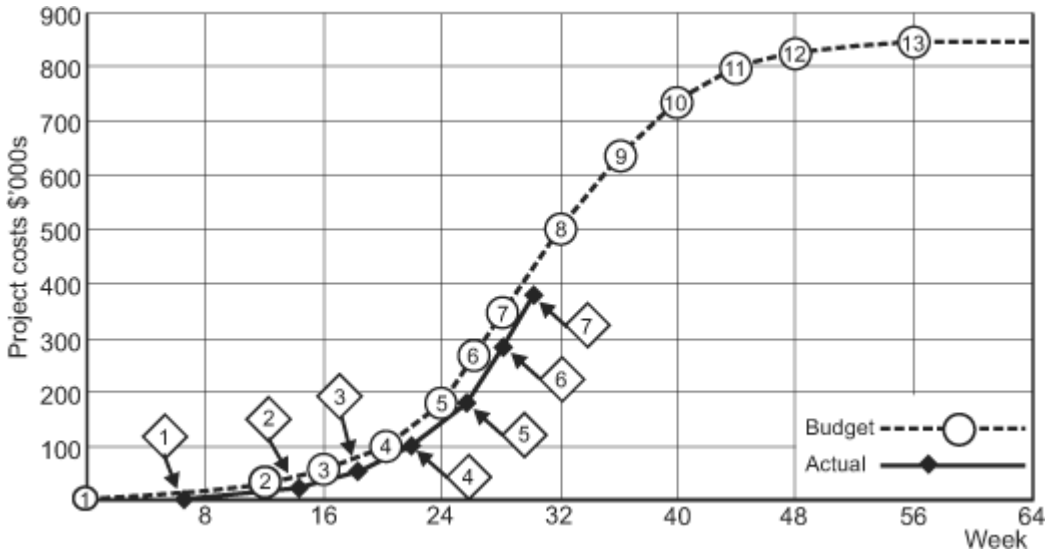


Figure 26.2 Project cost and achievement comparison using milestones

A Milestone Analysis Example

A small construction project lasting just over one year is the basis for this example and Figure 26.2 displays the relevant graphs. The scale of costs in this example would be appropriate to a flight operations center in an airline's hub. This would facilitate the work in terms of operations planning and operations and maintenance control for the airline and its crew members. Think here in terms of a building that would be separate from any of the terminal buildings but adjacent to the airport or on the airport property itself, the exact location being dependent on the specific airport.

The dotted curve in Figure 26.2 shows the time-scaled budget for the project, drawn by combining data from the project schedule and the authorized cost estimates. Thirteen milestones have been identified for the project, and the schedule and cost data for these are tabulated in Figure 26.3.

Each milestone has been indicated on the planned curve by placing a circle at the time when it should be achieved. The numbers within the circles identify the particular milestones.

Monitoring method Actual cost and progress data have been gathered up to the end of week 30 for this project and these are included in the tabulated data shown in Figure 26.3. The results have been plotted, at two-weekly intervals, as the solid line curve in Figure 26.2. Any milestone passed during

each two-weekly period has been indicated on the actual cost curve by means of a diamond containing the milestone's identification number.

Interpreting the results of milestone analysis Of course, if all is going exactly according to plan, the budget and actual graphs should lie together on the same path and the milestone points should coincide. When they do not, investigation should give some indication of the project cost and achievement performance to date.

	Milestone description	Schedule (week number) Plan	Schedule (week number) Actual	Cumulative cost $(1000s) Budget	Cumulative cost $(1000s) Actual
1	Project start authorized	0	6	0	0
2	Design approved	12	14	25	20
3	Drawings issued for building	16	18	60	55
4	Foundations completed	20	22	100	100
5	Drawings issued for services	24	26	180	180
6	All equipment for services ordered	26	28	275	290
7	Walls built to eaves	28	30	345	385
8	Windows and doors finished	32		500	
9	Roof on, building watertight	36		630	
10	Wiring and plumbing finished	40		730	
11	Services installed and tested	44		795	
12	Internal finishes completed	48		825	
13	Site and building handover	56		845	

Figure 26.3 Data for a milestone chart
These data were used to compile the chart shown in Figure 26.2.

Imagine that you are the general manager of the company responsible for this project and that it has been running for just over 8 weeks. If you look at week 8 on Figure 26.2 you will see that milestone 1, project start, has been achieved six weeks late, as indicated by the position of the diamond compared with the circle. The very low costs recorded at week 8 indicate that little or no activity is taking place. So, you can easily see that the project has started late and that more effort is needed urgently if progress is to catch up with the plan.

When you receive your updated milestone chart at the end of week 14 it tells you that milestone 2 has been reached. It should have happened at week 12, but the project has now been pulled up from being six weeks late to only

two weeks late. Costs recorded up to week 14 are $20 000. These costs compare against a budget of $25 000 for achieving milestone 2.

Expenditure at week 14 should have reached about $45 000 (the dotted curve). So you conclude that the project is still running slightly late but and that the rate of expenditure is lower than plan, so extra effort is needed. You are, however, getting value for the money spent because milestone 2 was achieved for $5000 less than its estimated cost.

If you continue to observe the chart at consecutive two-weekly intervals, you can see how it depicts the changing trend. In particular, the cost performance gradually deteriorates. One significant report from the project manager is the milestone chart updated to the end of week 28. The graphs indicate that milestone 6 should have been achieved at week 26 for a project cost of $275 000. You can see from the graphs, however, that milestone 6 has only just been reached at week 28 at a cost of $290 000. So the project is not only still running two weeks late but is now also $15 000 over budget.

By week 30, it is apparent that the project program, as indicated by milestone 7, continues to run two weeks late, and the costs at $385 000 have risen to $40 000 over the corresponding budget for milestone 7.

Without the milestones as measuring points, none of this analysis would have been possible.

Need for replotting If a change in project scope or any other reason causes rescheduling of work or costs, then the data for future milestones will obviously change too. The curve of predicted expenditure and milestones will have to be amended at each significant authorized change so that it remains up to date and a true basis for comparison of actual costs against plan.

Disadvantages of the Milestone Method

The milestone method suffers from a few disadvantages. These include the following:

1. The information that can be extracted for management use in controlling the project is often obtained after the damage has been done, and certainly much later than the predictions possible with more detailed earned value analysis (described below).

2. If program slippages are going to occur very often, the curves may have to be redrawn frequently, unless a computer can be used or some very flexible charting method is devised.
3. The method takes only an approximate account of work in progress (work packages which have been started, but where the milestones have yet to be achieved).
4. The method only shows coarse trends rather than the more detailed measurements obtainable with earned value analysis.
5. It is not easy to use the results of milestone analysis to predict the probable final outcome for the project.

However, the method involves comparatively little effort, is a considerable improvement on simple cost versus budget comparison, and may therefore commend itself to the busy project manager.

EARNED VALUE ANALYSIS

Earned value analysis can be regarded as the missing link between cost reporting and cost control. It depends on the existence of a sound framework of planning and control, including the following:

- a detailed WBS;
- a corresponding cost coding system;
- timely and accurate collection and reporting of cost data;
- a method for monitoring and quantifying the amount of work done, including work in progress.

The earned value process aims to compare the costs incurred for an accurately identified amount of work with the costs budgeted for that same work. It can be applied at the level of individual tasks or complete work packages and the data are usually rolled up for the whole project. The procedure uses the results to produce a cost performance index (CPI). If everything is going exactly according to plan the cost performance index will be 1.0. An index less than 1.0 indicates that the value earned for the money being spent is less than that expected.

Importance of WBS

The first stage in establishing an effective procedure for assessing achievement is to decide which work elements are to be subjected to measurement, analysis and reporting. In fact, this choice should be clear; the work packages from the project work breakdown, together with their cost estimates or budgets must provide the framework. It is important to carry this breakdown through to the level of activities performed by individual departments or work groups, so that each responsible manager or supervisor can be given quantified objectives that can be monitored by the earned value process.

Barned Value Nomenclature and Definitions

The following are a few of the names and abbreviations used in earned value analysis. The list is not complete but includes the most commonly used quantities.

Abbreviation	*What it means*
ACWP	Actual Cost of Work Performed at the measurement date.
BCWP	Budgeted Cost of Work Performed—this is the amount of money or labor time that the amount of work actually performed at the measurement date should have cost to be in line with the budget or cost estimate. It is usually necessary to take into account work that is in progress in addition to tasks actually completed.
BCWS	Budgeted Cost of Work Scheduled—this is the budget or cost estimate for work scheduled to be complete at the measurement date. It corresponds with the time-scaled budget.
CPI	Cost Performance Index—this factor indicates the measure of success in achieving results against budget. Anything less than unity indicates that the value earned from money spent is less than that intended.
SPI	Schedule Performance Index—this can be used as a measure of progress performance against plan, but is less commonly used than the CPI. Anything less than unity shows progress slower than that planned.

These quantities can be used in the following expressions:

$$CPI = \frac{BCWP}{ACWP}$$

$$SPI = \frac{BCWP}{BCWS}$$

CASE EXAMPLE: USING EARNED VALUE ANALYSIS ON A PROJECT TO RENEW PERIMETER FENCING AT AN AIRPORT

For this example of earned value analysis we have chosen a project comprising one main activity for which progress can be measured quantitatively without difficulty or ambiguity.

The perimeter of an airport has been safeguarded for many years by a chain link fence some eight feet high but, in view of the need for better security following the terrorist atrocities of 9/11, the airport authority has decided to install electronic sensors around the perimeter and to replace the old rusting fence with a new heavier gauge fence, topped with razor wire.

Two different sub-contractors have been employed. One of these will be responsible for the electronic alarms, which the airport authority is managing as a second, subsequent project. We are concerned here only with the other sub-contractor, whose task will be to replace the old fence.

The total length of fencing is about 8.5 miles, which we have approximated to 15 000 yards. The fencing project contract stipulates that the removal of the old fence and installation of the new shall take place continuously, working day and night (with portable gas powered floodlights during the hours of darkness). This is, therefore, almost a single continuous task project. The task will require two work gangs, working in partnership, so that as one gang removes a short section of the old fence, the other gang follows and, immediately, sinks new steel posts and fills the gap. Thus these two gangs will follow each other around the airport perimeter until the whole 15 000 yards of fence have been renewed and improved. Continuous working will ensure that at no time will unattended gaps be left in the fence that could threaten airport security. The scope, budget and schedule for this fencing project have been defined by the following data:

- total length of fencing to be renewed is 15 000 yards;

- estimated contractor's cost of labor and materials before mark-up for profit is $750 000;
- time allowed for the project from the first working day at the airport site is 200 days (which is about 6.6 months);
- the rate of progress is expected to be uninterrupted and linear;

When the above data are considered, the following additional facts emerge:

- budget cost per day = $750 000 divided by 200, which is $3750 per day;
- planned rate of building = 15 000 yards divided by 200, which is 75 yards per day;
- the budget cost for each yard of fence is $750 000 divided by 15 000, which is $50 per yard.

At the end of the second month, on day 35, the project manager has been asked to carry out an earned value analysis. The planned progress for the end of day 35, at a scheduled 75 yards per day, should mean that 2625 yards have been completed.

Now suppose that the fencing contractor and their quantity surveyor report the following measured performance data:

- length of fence completed at day 35 is 2250 yards;
- contractor's costs for those 2250 yards has been $120 000.

Earned Value Analysis of the Airport Fencing Renewal Project

From the project schedule, the project budget and the measurements at day 35 we can deduce the following data for the purposes of earned value analysis:

- the actual cost of work performed (ACWP) is $120 000;
- the budgeted cost of work performed (BCWP) is $(2250 × 50) = $112 500;
- at day 35 the scheduled amount of work is 75 × 35 which is 2625 yards;
- the budget cost of that work scheduled (BCWS) would be $(2625 × 50) = $131 250.

Now we can substitute these values in the earned value formulae to derive the cost and schedule performance indices, as follows:

Cost performance The cost implications of these data can be analyzed using earned value analysis as follows:

$$\text{The CPI} = \frac{\text{BCWP}}{\text{ACWP}} = \frac{112\,500}{120\,000} = 0.9375$$

The implication of this for final project cost can be viewed in at least two ways.

1. We could divide the original estimate of $750 000 by the cost performance index of 0.9375 and say that the predicted total project cost has risen to $800 000, which gives a predicted forecast cost overspend (variance) of $50 000 for the project at completion.
2. Alternatively, we can say that $120 000 has been spent to date to build 2250 yards of fence, so that each yard is actually costing $53.33. Thus the total 15 000 yards, if this level of performance continues, will cost $(53.33 × 15 000) which is $799 950, or a predicted overspend at completion of $49 950.

The apparent $50 difference in these results occurs because we expressed the actual cost of $53.33 in the second calculation to only two decimal places.

Schedule performance Earned value data can be used to predict the likely completion date for an activity or a project, although a straightforward comparison of progress against the plan is probably an easier and more effective method. If the earned value method is used, the first step is to calculate the SPI. For the airport fence at day 35 the SPI is found by:

$$\text{SPI} = \frac{\text{BCWP}}{\text{BCWS}} = \frac{112\,500}{131\,250} = 0.86$$

The original estimate for the duration of this project was 200 days. Dividing by the SPI gives a revised total project duration of about 233 days. So if this work continues at the present rate, the project can be expected to finish about 33 days late.

Methods for Assessing Progress in Earned Value Calculations

Most earned value analysis must be performed not just on one activity, as in the airport fence project just described, but on many project activities. At any given measurement time in a large project, three stages of progress can apply to all the activities. These stages are as follows:

1. task not started—earned value is therefore zero;
2. task completed—earned value is therefore equal to the activity's cost estimate or budget;
3. task is in progress or interrupted. Earned value for work in progress can often be assessed by measuring actual quantities of work done. For other, less tangible, tasks it is necessary to estimate the proportion or percentage of work done, and then take the same proportion of the current authorized cost estimate as the actual value of work performed.

Earned Value Analysis Prediction Reliability and Implications

Early predictions of final costs always tend to be unreliable. There are at least four reasons for this:

1. Estimates of progress, or of work remaining to completion are usually only judgments, and people tend to err on the side of optimism.
2. During the first few weeks or even months of a large project, the sample of work analyzed in earned value calculations is too small to produce valid indications of later trends.
3. There is no guarantee that the performance levels early in a project, even when they have been accurately assessed, will remain at those same levels throughout the remainder of the project.
4. Although many activities, especially in design, might be declared as 100 per cent completed, it is inevitable that further work will be needed when questions arise as drawings and specifications are put to use in manufacturing or construction. It is quite likely that some drawings will have to be reissued with corrections or modifications. Unless due allowance has been made elsewhere for this 'after issue' work, the project budget might eventually be exceeded.

Now it is time to introduce some words of severe caution concerning all earned value analysis methods. The first point to note is that these calculations are usually based not on concrete facts, but upon estimated progress. Whilst some tasks are capable of being judged according to physical measurement of work actually done, many other tasks are not and estimated progress can only be a matter for judgment, which will not always be accurate.

Earned value analysis performed soon after the beginning of a project can throw up some very spurious results because the quantity of work sampled is too small, in statistical terms.

Some people without scientific or statistical training are not familiar with the rule that any mathematical result should not be expressed to more places of decimals, or to more significant figures than the input data accuracy justifies. Thus to declare that a project will be overspent on its original budget of $1m by $50.35 would be plain daft, but we have both seen similar gaffes.

The earned value analysis method depends on good communications and upon everyone responsible for supplying progress and cost data to do so when required. It can be incredibly difficult to arrange that every project participant supplies data in time for each scheduled recalculation of earned value.

The project support office is often a good home for managing earned value analysis, and its staff should be able to assist in solving the communications problem by issuing reminders and pursuing defaulters to gather in every last bit of data required.

It sometimes happens that a task incurs expenditure before any progress is made. If expenditure of only one dollar is reported for a task with zero performance, the CPI for that task is zero. Then the computer will predict the final cost of that task (and therefore of the entire project) as infinity, unless the software is particularly ‘intelligent’.

Earned value analysis is labor intensive. It involves input from many people, most of whom are fairly senior and earn significant salaries. It therefore comes at a cost. And that cost does not add value to the project.

Earned Value Assessment for an Engineering Design Department

In a typical large aviation project the estimates of progress made in earned value calculations must be made for many tasks over many departments. In some cases these assessments will be relatively easy, especially where the departments concerned produce tangible products that can be seen and counted. However, some departments produce more abstract results, such as software programs or design drawings. We give here some observations on assessing engineering design progress, based closely on our experience in two different companies.

When reviewing the progress of all engineering design tasks in a project, one approach is to determine how many drawings and specifications are to be produced, and then divide this number by the number of drawings actually issued, multiply the answer by 100 and declare this as the percentage of design completed. Although some companies do use this method, it is really too crude because it fails to take into account all the conceptual design work needed, and assumes that the work involved in producing one drawing is equivalent to the amount of work needed to produce any other drawing. The method can however be used in limited cases, such as for a department which is producing a large number of similar drawings, like electrical wiring running lists or piping diagrams.

In most design jobs the only way to assess progress is to ask the engineer, or the engineer's superior, for an estimate. 'What percentage of this task do you consider has been achieved?' might be asked or, perhaps more provocatively, 'How much longer is this job going to take?' This process must be carried through all tasks in the project. The engineer might be guilty of unwarranted optimism or poor judgment when giving a progress report. This is the penalty that must be paid when changing from an objective to subjective assessment of progress.

Nevertheless, an answer of sorts can be extracted and, although by no means perfect, surely this is better than having no answer at all?

Work in progress assessments will inevitably be less accurate than the data for completed tasks. However, provided that work in progress accounts for only a small proportion of the total work, assessment errors should be diluted by the larger, more reliable, estimates for jobs that are definitely finished. This will, or course, be less true for short-term projects, or at the start of any project, where the proportion of work in progress to completed work may be high. If the individual tasks are large, owing to insufficient

work breakdown, then again the work in progress could rank high because it will take correspondingly longer to cross off the completed tasks.

Example An earned value calculation in an engineering design department is demonstrated in Figure 26.4 using a manual method. In this example an engineering project is well under way. The total department estimate (the total potential earned value) is seen to be 2975 work-hours.

An analysis of the work completed or in progress reveals that the BCWP is 1389 work-hours. This is the project earned value at the measurement date.

Against this achievement, the ACWP is seen to be 1142 work-hours. This figure represents all the hours actually booked to these jobs on timesheets. Although 46.7 per cent of the work has been done, only 38.4 per cent of the budget has been spent. This is a good result, and indicates that work generally is costing less than the budget.

Earned value analysis

Department: Engineering — Date: May 2011

Project: Sensor and servo control unit — Sheet: 1 of: 1

	Activity	Budget work-hours	Per cent achieved	Earned value BCWP	Actual cost ACWP
0001	System design	350	100	350	255
0002	Write system specification	35	100	35	35
0003	Design +25v power supply	105	100	105	140
0004	Breadboard stage	70	100	70	35
0005	Package	70	100	70	40
0006	Prove prototype	35			
0007	Write test specification	35			
0008	Design +10v power supply	105	100	105	65
0009	Breadboard stage	70	100	70	50
0010	Package	70	50	35	25
0011	Prove prototype	35			
0012	Write test specification	35			
0013	Design -15v power supply	105			
0014	Breadboard stage	70			
0015	Package	70			
0016	Prove prototype	35			
0017	Write test specification	35			
0018	Design sensor circuit	350	100	350	288
0019	Breadboard stage	105	100	105	124
0020	Package	105	40	42	50
0021	Prove prototype	70			
0022	Write test specification	35			
0023	Design servo and controls	175	20	35	15
0024	Breadboard stage	140			
0025	Package	70			
0026	Prove prototype	105			
0027	Write test specification	35			
0028	Design main frame	70	25	17	20
0029	System testing	70			
0030	Environmental tests	70			
0031	Write production test spec.	140			
0032	Write operating manual	105			
	Departmental totals	2975	46.7	1389	1142

Figure 26.4 Earned value analysis for an engineering department
Budgets, progress and actual costs can be compared on a sheet such as this as a preliminary step in predicting the final project expenditure.

Dividing the BCWP by the ACWP for this project gives a CPI of 1.22. If things are allowed to go on in the same way, the project budget of 2975 hours is likely to be underspent. Dividing by the CPI predicts a final engineering design department expenditure of only 2438 work-hours. The accountants would call this a positive variance of 537 work-hours.

Earned Value Analysis for Sub-contracts

Earned value measurement may have to include sub-contracted tasks. However, if the sub-contracted work is being obtained on a fixed-price basis, the sub-contractor carries the financial risk and earned value measurements for internal control are then the prime responsibility of the sub-contractor.

The project manager will have to pay close attention to the measurement techniques used by sub-contractors whenever they submit claims for progress payments. Such payment claims must be made against the achievement of recognizable events or be supported by certificated measurement. It is those results or other reports from the sub-contractors that the project manager must include in the earned value picture for the whole project.

EFFECT OF PROJECT CHANGES ON EARNED VALUE ANALYSIS

Every change introduced into a project can be expected to have some effect on the level of achievement attained by the departments involved. Before this effect can be measured, one significant question must always be answered:

> Can the customer be held liable for any additional costs, or must the additional work be paid for out of the existing budget (and, therefore, out of the potential profits)?

Control of project changes was dealt with in Chapter 23. It can be assumed that, long before any modification reaches the stage of implementation, the change committee or other designated authority will have ensured that every approved change is clearly defined as ‘customer funded’ or ‘unfunded’.

Unfunded Changes

Each unfunded change will affect the total workload remaining, usually with no corresponding change to the authorized budgets. In most cases changes increase the remaining workload, so that the proportion of earned value achieved is depressed in all the departments affected.

It should be possible to make an appropriate correction to the achievement measurement for each department to allow for unfunded changes. Each

modification would have to be added to the task list, along with a cost estimate for the additional work needed. Change costs are, however, often extremely difficult to estimate and record, because of the way in which the work is intermingled with the original task affected.

There can, of course, be no corresponding increase in the authorized budget. But for practical purposes, such adjustments are unnecessary, and unfunded modifications can be ignored provided that:

1. they are not too numerous or horrendous;
2. they do not cancel out work already reported as achieved.

Work on unfunded modifications will therefore show up as apparent overspending—which is of course just what it is. Earned value predictions will tend to be self-correcting as these overspends are picked up, even if they are not immediately identifiable as being expressly due to unfunded modifications.

Completed work rendered void by unfunded changes Unfunded changes that nullify work already carried out must always be taken into account by erasure of the relevant earned value elements from the records. This should be done for every department affected, and either whole tasks or parts of them may have to be reinstated into the remaining workload. In this way, the earned value calculations can be kept on a true course.

Suppose, for example, that in the case illustrated by Figure 26.4 there arose a modification which demanded a complete restart of tasks 0018, 0019 and 0020 (the sensor circuit design). Earned value for this item would have to revert to zero, which would mean subtracting 497 work-hours from the column total of earned value. This would cut the earned value for the project back from 1389 to 892 work-hours. The CPI has been cut from 1.22 to 0.78 and the predicted cost at completion becomes 3809 work-hours.

Customer-funded Changes

Funded changes can be considered as new tasks, for addition both to the task list and its authorized budgets. The customer should be asked to pay for any work which is scrapped as a result of the change, in which case that work

can be considered as having been sold and, therefore, achieved. It need not be subtracted from the achievement tally.

PREDICTING AND REPORTING PROFITABILITY FOR A WHOLE PROJECT

Once a basis has been established for the collection of earned value statistics from all parts of the project organization, it is a logical and progressive step to put all these results together into a composite prediction of total project costs.

Of course, the first such prediction is that made before the start of the project, when the initial cost estimates and budgets are prepared and when progress can confidently be declared as zero.

Subsequent analysis and cost predictions can be regarded as a continuous process by which the original estimate is steadily refined. As more work is completed, the total estimate to completion contains an increasing proportion of actual cost data, so that the predictions should become more accurate.

For cost-control purposes, it is necessary that these data are presented in a way that shows unwanted trends as early as possible, before it becomes too late for anything to be done.

Spreadsheet Presentation

Project cost summaries and predictions are commonly presented in tabular or spreadsheet form. Figure 26.5 shows a widely used arrangement, suitable for preparation from purely clerical methods or from computer systems. Tables such as this are typically bound into regular cost and progress reports, often produced at monthly intervals. A description of this format on a column-by-column basis will serve to round off this chapter with a reiteration of the principles embodied in the interpretation of cost and progress data. The spreadsheet columns have been labeled A, B, C and so on, for ease of reference.

The report form is headed with the project title and project number information. The report date is important, being the effective common reference date for all measurements and progress assessments.

The time lag between the effective report date and the actual report issue date depends on the size and complexity of the project to a great extent: it obviously takes more time to collect results from a project spread over a large, geographically scattered organization than it would where the whole project is conducted within one office or factory. Nevertheless, all possible steps must be taken to produce these reports before they become outdated and too late to provoke constructive management response.

Column A lists the main work packages from the project work breakdown. This list must include all cost items, including software tasks and summarized miscellaneous items. If more detail is required, this can be provided on backup sheets.

Column B gives the cost code for every item. This makes it easier to refer back to the original estimates and budgets and to audit the data presented.

In column C the original budgets for the work packages are shown, and these add up to the total original project budget at the foot of the column. This is the cost budget originally authorized and approved, which should be equal to the original cost estimates. Consideration must be given to the inclusion or otherwise of escalation and other below-the-line estimates and it may be necessary to add explanatory notes in the accompanying report text.

As the project proceeds, it can be expected that a number of variations or modifications will arise that are agreed with the client, and for which the client will pay. These must obviously increase both the project revenue and the budget. Budget increments from this cause are listed in column D. These, when added to the original budget for each project section give the current revised authorized budgets, in column E (the current budget).

In any project of significant size there are usually variations under consideration or awaiting approval that could ultimately affect the budget (and progress assessment). Until such variations have been agreed with the client it is obviously not possible to take the additional revenue for granted. It may, nevertheless, be of considerable interest to know the value of any such proposals which happen to be ‘in the pipeline’ at the report date. Although not shown in the example of Figure 26.5, a column can be included in the report layout, if desired, to give this advance information.

Column F lists the costs actually recorded as at the report date. These comprise the ACWP and include the following:

Project cost report summary Page of

Project title: Project number: Report date:

A Item	B Cost code	C Original budget	D Authorized budget changes	E Authorized current budget	F ACWP	G BCWP (assessed)	H CPI	J Forecast costs remaining (E-G)/H	K Forecast costs at completion F+J	L Forecast variance at completion E-K

Figure 26.5 A tabulated project cost report
A tabular project report that uses earned value analysis to forecast costs remaining to completion.

1. all labor-hours booked to the project (on timesheets or job tickets) converted at standard cost or other appropriate rates into the project control currency;
2. overheads and administrative costs;
3. payments for directly relevant insurance premiums, licenses, legal fees and consultants' fees;
4. payments made to, or legitimately claimed by, sub-contractors;
5. the cost of all materials committed, which includes the cost of all materials and equipment already used or delivered, plus the value of all other materials and equipment for which orders have been placed at the report date. in all cases freight, packing, insurance, agents' fees and duties paid or committed must be included;
6. any other costs incurred or committed up to the report date than can be directly attributed to the project.

Column G is obtained as a result of earned value analysis using the methods described earlier in this chapter. It shows the assessed earned value of all project work performed at the report date.

In column H the CPI has been calculated from the data in columns F and G. If the CPI is shown on an item-by-item basis, as here, any variation between the different work packages might be useful management information.

Column J forecasts the costs remaining to completion, obtained by factoring estimates for work remaining by the CPI.

Column K indicates the best prediction possible of the final, total project costs at completion. As time passes, the forecast element of this figure will become less, the proportion of actual costs will become greater, and the final prediction will grow more accurate.

The final column, L, highlights any variances between the authorized budgets and the predicted final costs.

POST-MORTEM

When the project is finished and the final costs become known an investigation can be conducted to compare the actual expenditure with the original estimates. Such postmortem examinations are obviously far too late to be of benefit to the completed project, but they can be helpful in pointing out mistakes to be avoided when estimating or conducting future projects.

CASE EXAMPLE: ATM PROJECT

All the names and locations in this project are imaginary but this case is loosely based on an actual project that was completed successfully not long ago. We have included this case because it is an example of a very well run project in which many recommendations made in our earlier chapters were followed.

Project Background

Politania is a land-locked country with a very busy airspace. The Politanian national government entrusts all air traffic management (ATM) within its airspace to a private company called Mega-ATM Inc. This company employs approximately 1400 people of whom 600 are air traffic controllers. It has offices or installations at ten different locations within Politania including the

country's two international airports. Politania's ATM operator, Mega-ATM, is a well-respected operator in the global aviation scene and a founding member of CANSO, the Civil Air Navigation Services Organization, the international organization that represents ATM operators globally.

Initial staff training and regular refresher courses for all Mega-ATM operators are conducted on simulators located in the Mega-ATM training center. These simulators comprise the following:

- two basic simulators, which are used for initial staff training;
- two radar simulators, used for upper airspace ATM training;
- two tower simulators (coded TOSIM), used for training control tower personnel.

Responsibility for the operation and engineering of these simulators is assigned to two separate groups within Mega-ATM. These groups are:

- the simulator operations group (SOG) from the operations department. This group is responsible for the operation of the simulators (definition of the exercises, organization of the training sessions);
- the simulator design group (SDG). This group is particularly responsible for simulator upgrades to improve functionality and capability.

Principal Project Objectives

Early in 2007, the SDG received authority from Mega-ATM senior management to proceed with a technology-driven project to replace core elements of the two existing tower ATM simulators, both of which had been in service for several years. The objectives of this project were to:

- Modernize the software protocols to enable easier maintenance and future changes.
- Ensure the future evolution of the equipment by facilitating the addition of new equipment in the future, thanks to a modular architecture.
- Unify the simulation platform environment between the tower and radar simulators by using a common gateway application.
- Internalize the know-how residing in the SDG, so that they would be more capable of carrying out future improvements. Previously, this

know-how was in the hands of an external company. The senior management of Mega-ATM believed that competencies in the simulation environment should be part of the company's core business and should therefore be confined to in-house staff.
- Make possible the addition of a test platform dedicated to testing and proving future new improvements to the tower simulator. This should come about automatically as a natural result of the upgrades proposed during this project, but it was written into the project specification as a specific objective.

Note that this was a management change project, with internal funding (what we classified as a Type 3 project in Chapter 1). Thus there would be no profit immediately at the end of the project but instead the company would be expecting longer-term benefits to be realized in the future.

Project Organization

Figure 26.6 sets out the key elements of the ATM project organization. Many parts of the routine operational organization of Mega-ATM have been omitted for clarity. This project organization is clearly an overlay matrix, which means that it is overlaid on the existing organization and the project manager and functional managers have some joint responsibility. So the project manager has what might be described as a strong coordinating role. Fortunately within Mega-ATM harmonious relationships have always existed generally between managers, and indeed between managers and staff. So none of the difficulties sometimes associated with the dual responsibilities that are so characteristic of matrix organizations were experienced. The project manager was, in fact, a senior member of the SDG, and only half this manager's time was needed for these project management duties.

There were some line authority relationships within the ATM project organization because the project manager reported directly to a steering committee appointed by senior management to oversee the project. Further, the project manager here had direct line authority over a project support office. It was this project support office that carried out all detailed planning and progressing tasks, registered and progressed change requests, monitored costs (in collaboration with the accounts department) and assisted the project

manager in preparing regular progress reports to senior company management.

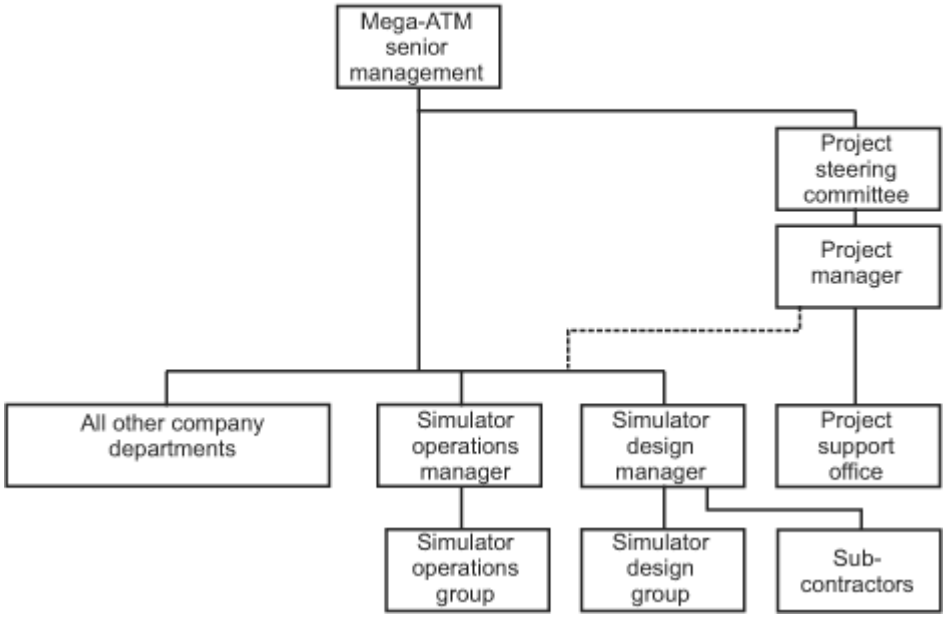


Figure 26.6 Outline organization of the ATM project

Project Management Methodology

The manager of the ATM project had the clear starting advantage of a well-produced and proven company project management handbook. This company manual had been developed by Mega-ATM over several years, incorporating lessons learned from previous projects. It describes a number of project management procedures that follow proven tradition, with templates for reports and guidelines on which procedures should be chosen, depending on the type and size of each new project.

For the ATM project, following its detailed definition, the project work program was structured on a simple but logical WBS, and a number of critical milestones were identified as cost and progress markers. Each milestone marked the planned transition from one project phase to the next.

Progress milestones The ATM project was structured in seven phases. The accomplishment of each phase was marked by a designated milestone:

1. Phase 0, limited project authorization and start, marked by Milestone 0.
2. Phase 1, initial system study and elaboration and clarification of the project concept contained in the business plan. This phase was to conclude at Milestone 1.
3. Phase 2, final conceptual study and revision of the original business plan in readiness for full project authorization. The end of this phase would be marked by Milestone 2.
4. Phase 3 would mark full project authorization, allowing detailed planning, announcement of the business case and project objectives, and mobilization of full project resources. This phase would conclude at Milestone 3.
5. Phase 4 would be the main working phase of the project, culminating at Milestone 4 when the systems were engineered and ready for trials.
6. Phase 5 was designated for commissioning and advance training trials. The end of this phase, at Milestone 5, would be marked by the decision to put the upgraded simulators into full use. By the achievement of this milestone most of the project expenditure would have been incurred.
7. Phase 6 was to be a concluding phase, with all the systems settling down and becoming stabilized, with all bugs removed and in full operational use. At Milestone 6 the project would be closed, with a final debriefing meeting.

Advantages of the Mega-ATM structured approach to this project This ATM project was given a good chance of success from the outset by its structured approach and adherence to proven project management methods. This approach meant that:

- the project manager was guided by the company's project handbook, which was a great support thanks to its well-defined templates and helpful checklists;
- projects within Mega-ATM always follow the same structure, allowing project managers to always work in the same way;
- project controlling was made easier for the middle and top management thanks to the structured approach and familiar report templates.

The Mega-ATM project handbook classifies all its projects, whether internally or externally funded, according to their importance in terms of

expected investment. Depending on the classification, different levels of management are responsible for accepting the different milestones. The ATM project was classified as a Type C project, the smallest possible type, owing to its relatively small scope and total estimated costs of $380 000.

Mega-ATM followed more good practice in reviewing the project cost estimates at each milestone. So this estimated total cost of $380 000 was the estimate at Milestone 1. Just how these estimates developed as the project progressed can be seen in Figure 26.7. This development is interesting on several counts. The project seems set to finish below the early estimate of $380 000, but note the mild concern that must have been aroused among Mega-ATM's senior managers when, at Milestone 3, an overspend of $7 000 was being predicted. Of course, many modern projects have achieved notoriety by wild excesses in expenditure and most managers would be delighted with such a low overspend prediction.

The final cost estimate for this project reduces to $326 000 nearer the end of the life cycle. Within this total there are some fairly wild variations in the cost estimate details which indicate that this company needs to improve its cost estimating standards, even though the ATM project outcome seems set to be very satisfactory.

Other projects at Mega-ATM involve more risky technology and the company often experiences significant increases in the project costs above estimates as projects progress. The introduction of quality standards (ISO 9000) and safety standards (ESARR) have also increased project costs, mainly in the areas of documentation and training.

The cost breakdown shown in Figure 26.7 needs a little explanation. The total project costs will be capitalized (amortized over the lifetime of the equipment) once the equipment is put into operation with the exception of operator's costs, which are regarded as an annual operating expense.

The external investment costs shown here represent invoices for sub-contracted external staff working on the project and the costs of acquiring hardware and software. The internal costs comprise salaries of Mega-ATM staff employed on the project. The estimated travel costs (most of which clearly failed to materialize) were intended to cover personnel travel costs between the company headquarters, its training center, and one or two other sites where associated equipment is located.

	At milestone 1	At milestone 3	At milestone 5
External costs	$147 000	$152 000	$150 000
Internal costs	$148 000	$185 000	$152 000
Travel costs	$ 70 000	$ 40 000	$ 18 000
Operator costs	$ 15 000	$ 10 000	$ 6 000
Total project costs	$380 000	$387 000	$326 000

Figure 26.7 ATM project cost estimate revisions at different times in the project life cycle

Project Scheduling

Project scheduling was one of the most important tasks of the project manager of the ATM project, who was assisted by the project support office. Microsoft Project was used to produce a Gantt chart and work-to lists from a critical path network. All duration estimates were deterministic so that PERT (with its triple probabilistic estimates) was not considered necessary. The project manager achieved a sensible level of task breakdown, which had neither too much, nor too little detail to enable day-to-day progress control. Figure 26.8 shows the Gantt chart.

However, most of the tasks were on the critical path. This meant that the project carried some degree of risk, but this was counteracted by effective day-to-day progress management and the high motivation of all the staff involved in the project. Although it is not ideal to have a large proportion of critical tasks in a schedule, this sometimes cannot be avoided. It all depends on the logic pattern and nature of the project.

Control and Reporting

Labor time A weekly timesheet system allowed all labor times to be recorded in hours allocated to WBS tasks. The project manager used Microsoft Excel to produce reports in which budgeted and recorded hours were compared. Overspends were highlighted in red. Two different timesheet methods were employed, one for the internal staff of Mega-ATM and the other for external staff. Monthly invoices from external staff and staff agencies were checked and authorized against the times entered on timesheets. The consolidated Excel timesheet report proved to be a powerful

tool for the project manager to detect, in particular, the tasks which consumed more resources than budgeted.

With this approach, the project manager did a very good job of controlling the time spent on each activity of his project. This was a good example of how a project manager can efficiently (and in a simple way) compare the resources used on the project with the labor budgets.

Monthly Project Reports In addition to the internal weekly reporting, the ATM project manager had to report progress on a monthly basis to the steering committee. Apart from being common sense, this was a requirement specified in the Mega-ATM project handbook. Each monthly report contained:

- overall indicators for key aspects of the project;
- cost performance summary;
- schedule performance summary.

The monthly reports also contained reports using a simple kind of earned value analysis, and the report format is shown in Figure 26.9. However, the cut-off for these reports was annual, and not the end of the project. The 'expected amounts' were estimates by made the project manager for the relevant year. These estimates were reviewed each month and helped Mega-ATM's accountants to estimate the cash needed by the company in the current year.

Another section of each monthly report reviewed the planned dates of future milestones and presented the current assessment of whether or not progress was on track.


Task Name
UMT-BEAM
1 Phase 1 : Survey
1.1 MS1 : Proposal paper
1.2 MS1 approval
2 Phase 3 : Conception and specification
2.1 UMT-BEST Analysis
2.2 Software requirements specifications
2.3 Use case specification
2.4 Test environment specification
2.5 MS3 : Business case
2.6 Beam knowledge transfer
2.7 MS3 approval
3 Phase 5 : Development and tests
3.1 Test environment installation and settings
3.2 DevTestInstallation UMP
3.3 DevTest BEAM
3.3.1 Implement/Test BEST Protocol
3.3.2 Implement/Test UMT-BEAM configuration
3.3.3 Implement/Test (incoming) BEST use cases
3.3.4 Implement/Test VISUAL interface and use cases
3.3.5 Implement/Test SAMAY protocol and use cases
3.3.6 Implement/Test TACO protocol and use cases
3.3.7 Implement/Test INFOSIM protocol
3.3.8 Implement/Test STATUSIO protocol and use cases
3.3.9 Implement/Test FLUKID protocol and use cases
3.3.10 Implement/Test TLC protocol and use cases
3.3.11 Implement/Test UMT-BEAM GUI
3.3.12 Integration tests
3.4 Test case specification
3.5 UMT-BEST maintenance and specification
3.6 MS4 : SAT
3.7 Deployment on site
3.8 Test on TOSIM Yellow
3.9 Write User guide and documentation
3.10 MS5 : Clearance for Operation
3.11 MS5 approval
4 Phase 6 : Stabilization
4.1 MS6 : Final debriefing
4.2 MS6 approval

Figure 26.8 Gantt chart of the Mega-ATM project produced using Microsoft Project

	Current year					
	Budget released	Eng.	Real	Eng. + real	Expected	
					Previous	Current
External investment	40.0		33.4	33.4	35.0	33.4
Travel expenses		0.1	4.4	4.5	32.5	14.5
Internal investment			39.8	39.8	125.0	90.0
Revenues						
Totals ($'000s)	40.0	0.1	77.6	77.7	192.5	137.9

Figure 26.9 Format of Mega-ATM's monthly reported annual project cost forecast

Project Outcome

In June 2008, the ATM equipment was successfully put in operation with a delay of four months compared to the original schedule and with costs some 15 per cent under budget. This was considered to be a successful achievement for the project manager and for the SDG.

27
Project Closedown

The project life cycle does not end for all the project stakeholders when the initial work is done and the project organization is disbanded. Even when all the scheduled tasks have been done successfully a number of loose but important ends always need to be tied up. When the project has resulted in handing over a software system or a hardware product (anything from a piece of equipment to an air traffic control system, a fleet of aircraft or a major airport facility) the project contractor usually has an ongoing duty to provide support to the project owner for training, maintenance and operational advice. For internal management change projects, the closedown of the initial project often signals the start of a difficult operation to implement the intended change and ensure that the intended benefits are realized in the longer term.

REASONS FOR CLOSING A PROJECT

Every project manager hopes that the end of a project will coincide with the achievement of all the original targets (deliverables) and no dissatisfied stakeholders. But even the bestled projects do not always end successfully and a few projects might have to be ended unexpectedly. For example:

1. The project contractor runs out of money (leaving everyone with big problems).
2. The customer runs out of funds and fails to make progress payments so the project must be canceled or put on hold for an indeterminate period.
3. The customer decides to make fundamental changes, causing the original project to be scrapped and replaced with a new project.
4. Your company has been taken over by another and the new management team decide to scrap a management change project (or an R&D project) that is already in progress.

5. Changed economic or political conditions remove the original justification for the project in the business plan (for example, a recession means that a predicted doubling in the demand for air travel will not now happen in the foreseeable future).
6. A change in Government policy causes termination of a project. Defense contracts for weapons systems and aircraft are always subject to such risks, but even large commercial projects can be adversely affected by government policy.
7. An Act of God (flood, tempest, earthquake, lightning strike, tornado, hurricane, erupting volcano, tidal wave, wildfire and so on) causes a project to be suspended or abandoned.
8. A civil war or other hostile activities cause airport development to be stopped or make an intended new international route too dangerous to open.

However, most of the sections in this chapter are based on a happy ending to a successful project.

FORMAL PROJECT CLOSURE

Just as it was necessary to issue a formal document of authority to open a project and allow expenditure to begin (described in Chapter 7), so the end of a project or its indefinite interruption must be marked by a formal announcement that stops further expenditure and sets the closure procedure in motion.

Cost Cut-off

The most significant reason for issuing a formal project closure notice is to stop further expenditure against the project accounts. Projects that have finished successfully within their labor budgets can easily become overspent if timesheet bookings to the project accounts are allowed to continue simply because those accounts still happen to be live. It is well known that the recording of hours on timesheets is open to abuse; there is always a tendency for the less scrupulous members of staff to try and ‘lose’ unaccountable or wasted time by booking it to large projects where, it is hoped, it will go unnoticed (buried). Good supervision and timesheet audits will minimize this

risk, but closing the accounts in the computer is a far safer way to block time bookings to finished projects.

The organization's cost and management accountants may wish to hold some project accounts open for their own use beyond the official project closure date to collect a few tail-end costs. Even when labor time bookings are forbidden after the closure date, there are usually items such as late invoices from suppliers and sub-contractors to be accounted for. On a large project these can continue to arrive for several months after project completion (even 18 months for one project in our experience).

Although post-project cash movements can represent considerable sums, they will not affect the calculated profit significantly if these costs have been correctly accrued in the accounts. Every project manager should ensure, for example, that the costs of all project purchases are reported and allowed for in forecast profit and loss accounts at the times when they were committed (that is, allowed for as soon as the amounts were accurately known, when the purchase orders were first issued). A similar argument applies to subcontractors' charges, because these can be assessed and accrued in the accounts before the final invoices arrive.

Project Closure Document

The closure document need only be very simple. It could even take the form of a notice that simply states 'To all staff please note that Project # XYZ will be closed on (date)'. But for most aviation projects post-project documentation is especially important and the closure notice might have to include some specific instructions. We recommend that a formal project closure notice should be issued with the following elements included:

- project title;
- project number;
- the effective closure date (after which no more labor time may be booked to the project accounts);
- any special instructions;
- signature authorizing the closure;
- distribution list, which ideally should be the same as the initial project authorization distribution.

An example of a fairly comprehensive closure notice is given in Figure 27.1.

AUTHORIZING POST-PROJECT EXPENDITURE

It is common for large projects to leave considerable closedown work in their wake, and that work has to be budgeted and controlled. There are at least two ways of authorizing such expenditure. One is to open a new small project especially for the purpose, restricted strictly to the closedown activities. The other way is to announce a budget for closedown activities on the project closure notice, complete with its own cost codes within the original project's WBS.

Although a guillotine must be imposed on time bookings at project closure, large aviation projects often need considerable documentation work after their finish dates. This documentation might require considerable effort, although much of this can be assigned to relatively inexpensive clerical and junior technical staff. The project support office, when such exists, is often involved. Just how well such tasks are performed depends to a large extent upon how much money the contractor is prepared to spend on them. Best practice is to keep all documentation as up to date as possible during the active course of the project, so that updating and filing or archiving at the end of the project requires as little additional effort as possible.

In some companies final documentation will be treated as an overhead expense, while other companies might be more fortunate in rarer cases by having budgets and funding contractually agreed with their clients for this purpose. Whether treated as an overhead cost or as a directly recoverable expense, post-project work should be regarded and managed as a defined work package, clearly and separately identifiable from the main project. It should ideally be allocated its own, separate, strictly budgeted account number. This work, all in-house and under local supervision, should be relatively easy to monitor and control. It is prudent to limit authorization on such work to a few named individuals, so that only timesheets bearing the staff names or roll numbers of these people will be accepted by the computer for bookings against the closure account.

The form illustrated in Figure 27.1 not only announces project closure but can also be used to act as an authorization document for a limited amount of expenditure on the post-project work package. By no means claimed to be typical, this example would clearly need modification in practice to suit each

company's own project circumstances and management systems. It does, however, demonstrate a method that can help to ensure the orderly closedown of a project. This example not only states the budgets allowed but it also includes a checklist of all the final project activities, together with some management directives regarding the disposal of documents.

Notice of project closure

The following project will be closed to time bookings and all expenses with effect from the date given below

Client: **BB Luxury Airlines Inc** Project number: **YY1340/25**

Project title: **YY1340 cabin upgrade for BBLA** Closure date: **29 Apr 2011**

The following budgets are hereby authorized for the closedown activities marked in the checklist below

Department	Labor-hours by standard cost staff grade						$
	1	2	3	4	5	6	
Design engineering	10			20	40		7 000
Project support office				10			500
Purchasing			15				800
Installation and commissioning							None
Flight testing	5		5				3 250
Computing				3			150
Records and archives			10		80		10 900
TOTALS	15		30	33	120		22 600

Special instructions:

Take special care with document filing and keep special tooling. Customer indicates a possible further order for 5 more aircraft to this special build standard within two years.

CHECKLIST OF PROJECT CLOSURE ACTIVITIES	
Project case history	**PM to write, keep it short**
Project specification	**Keep final specification indefinitely**
Project variations	**Keep the register**
Drawing list	**Keep. Review every ten years.**
Design calculations	**Keep indefinitely in engineering files**
Our drawings	**Check they are as-built and keep indefinitely**
Client's drawings	**Not applicable to this project**
Purchase control schedules	**Keep 10 years in engineering files**
Suppliers' drawings	**Keep 10 years,then review**
Purchase orders	**Keep 10 years, then destroy**

Inspection reports	Keep indefinitely
Test certificates	Keep indefinitely
Operating/maintenance instructions	Keep indefinitely
Spares lists	Keep and update periodically as necessary
Maintenance contracts	Not applicable - customer's responsibility
Sub-contract documents	Keep 10 years
Correspondence files	Keep 10 years
Final cost records	Keep 10 years
Photographs	Edit. Discuss with publicity dept
Critical path networks	Destroy after 1 year and erase computer files
Management information system	Delete project from MIS at end of 2018
Prepared by: Christina Burns	Project manager: Lisa Su / Approved by: Bradley Rubinstein

Figure 27.1 Project closure notice with checklist

FINAL PROJECT COST RECORDS

Final cost accounting information provides an important databank from which comparative cost estimates can be made for future projects. This is especially true of the labor time records (usually expressed in hours). Costs for materials and purchased equipment and the conversion of labor times into direct costs plus overhead, although important, are not quite so useful to future investigators because they will eventually become outdated through cost inflation.

Those subsequently needing to retrieve and compare information from any of these cost records will find their task made immeasurably easier if all the data have been filed under a logical, WBS-based and standard cost-coding system that has been rigidly applied across all projects.

DISPOSAL OF SURPLUS MATERIALS

Surplus materials and components often clutter stores and work areas after completion of a project. Sensible consideration must be given to the most cost effective method of their disposal. If they can be pre-allocated for use on other known projects, then clearly they can be stored for that purpose (with strict observation on aircraft projects to the rules of inspection release documents and so on that will provide future traceability).

Some specialized components may be saleable to the customer as part of a recommended holding of spare parts. Other items may be returned to common stock, sold, or (if necessary) scrapped.

Redundant stocks must not be allowed to accumulate because they represent a useless investment in money and space. It might be argued that quantities of very tiny, low-cost items take up little space and represent insignificant investment ('worth keeping because they might come in useful one day') but even these can cost time and money to store, and to count at each annual stocktaking. If surplus project materials and components remain in stores their value can be expected to slide steadily downwards towards zero as they deteriorate or become obsolete. Sell them if they have some value or otherwise get rid of them.

FINAL PROJECT AS-BUILT DEFINITION: THE END OF A CONTINUOUS PROCESS

Chapter 3 described the project definition process, and Figure 3.1 showed how this process can develop throughout the life cycle of a project. Clearly the definition of any substantial project does not end until after the project has been finished, when the last drawing or specification has been updated, registered and securely filed.

Formal project variation, modification, production permit and concession procedures are all part of this project definition process (see Chapter 23 on managing changes). The project manager or engineers must ensure that all deviations from drawings allowed during the course of the project are accurately incorporated in the final versions of those drawings. This can be a particularly significant problem where commissioning work has taken place at an airfield or other site remote from the contractor's home office. Small changes (for example corrections to electrical wiring) might be made by the commissioning engineers and clearly those engineers must communicate such changes back to the home office design team to ensure that the officially filed drawings are updated. The finished drawings, when they are archived, must record the true state of the project 'as-built'.

Knowing the as-built condition of every project is vital if the project contractor is to be able to fulfill its post-contract obligations to the customer.

For many aviation projects this will probably also be a statutory requirement of the relevant regulatory bodies.

AS-BUILT RECORDS OF GROUND-BASED PROJECTS

For construction and all other ground-based projects (such as the provision of airport facilities and systems) as-built project definition is important for post-project services such as operating and maintenance, training and so on. Further, when expansion of an existing facility or system is required by the original customer, the existence of a complete set of accurate drawings and specifications provides a convenient launch pad for the new project design.

Engineering Design Drawings and other Records

For engineering design records the first need is clearly to keep a set of project drawings. Sometimes clients who have paid for the engineering design of a project will consider all project drawings to be their own property. The client's own drawing sheets may even have been used. However, the contractor will still want to keep a complete set of drawings on its own files.

The key to indexing and defining all the drawings at the end of a project is either the central drawing register or, preferably, specific project drawing schedules. For manufacturing projects, bills of materials or parts lists arranged in WBS hierarchy will identify all the project drawings.

The final project drawing register or set of drawing schedules should list every drawing used in the project and give its drawing number, title and correct revision number. This discussion has particular application to airport construction projects as airport master plans are incredibly important for airport regulatory certification and re-certification and master plans are the cornerstone of these important regulatory requirements.

Documenting Purchased Equipment

For the purposes of illustration, suppose that a client has formally accepted the handover of an airport terminal building from the project's managing contractor. Everything has been managed for the client in a turnkey project, including the construction of the building, purchasing and installation of all

the plant and equipment, partitions, finishes, furnishing and other equipment, and final commissioning. The managing contractor will have some ongoing contractual obligation to the client in ensuring that the terminal facilities are up to specification for some time after project handover. There might also be follow-up responsibility to the client for arranging service under guarantee, assisting with operating problems, and in being able (if required) to carry out future modifications or extensions to the terminal.

To provide such a post-project service, the contractor needs adequate technical records of the equipment that was purchased from (and in many cases installed by) its external suppliers and sub-contractors. These records have to be obtained from the vendors during the course of the project in the form of layout drawings, technical specifications, operating and maintenance instructions, lists of recommended spares, lubrication charts, test certificates and so on.

In most cases at least one copy of all such documents would be sent to the terminal owners but every prudent managing contractor will retain a set. While it should theoretically always be possible to go back to the relevant vendor or sub-contractor for information in the event of a subsequent problem, companies have a distressing habit of going out of business, or of losing their former identities in mergers and takeovers.

There may also be a considerable benefit to the main contractor in keeping detailed records of equipment purchases, because these can often be of use to engineers when considering equipment for future, non-related projects.

Purchase schedules On large capital projects such as airport developments the purchase schedules are the main index of purchasing documentation. The relevant purchase specification numbers (with their correct revision status), supplier and purchase order details should all be traceable through this route.

Design Calculations

Design calculations are a vital part of project records. It is essential that these are numbered, indexed and stored with at least as much care as that given to the main drawing files. They may be called for in the unfortunate event of subsequent malfunction or structural failure, especially if personal injury results.

Change Documents and Inspection Certificates

All contract variations, modifications, engineering change requests, concessions, production permits, final inspection reports, test certificates and similar documents that help to define the final design status and quality of the project should be filed and indexed.

Correspondence Clearly all correspondence with customers, suppliers and subcontractors can have post-project contractual significance, so procedures must be in place for the safe keeping of these, The Statute of Limitations, will usually suggest that all such documents, and others relating to taxation and similar issues, should be kept for at least six years.

For aviation projects some documents will have to be kept for as long as relevant aircraft are flying, in case of difficulties in the future.

This is not the place to describe basic office administration but some project managers find difficulty in directing correspondence to appropriate files. The most important aspect in this respect is to have an index with the files into which every significant communication has been entered by project clerks. Then a future search of the computer files will readily locate all documents relating to a particular subject within each project long after the projects have been finished and closed down. We suggest that every index entry should allow a search by subject keywords. Thus any document should be retrievable even if only the vaguest memory of its source or even existence is known.

Case History or Project Diary

If sufficient time and money can be spared for the purpose, it is useful for the project manager to write a brief case history or diary of the project. This document does not have to be a literary masterpiece, but it should record every significant event, and list all serious problems together with their solutions. When filed with the project specification, minutes of meetings and other key documents, a case history become a valuable asset in the future if legal or other questions should arise about the project.

Reference to past case histories can also help when formulating the strategy for new projects. Reading about past mistakes can help new

managers to avoid repeating similar mistakes in the future. ‘Lessons learned’ should, therefore, feature as a main heading in every project diary.

This, in particular, is a document that can be written in diary fashion as the project journeys through its life cycle.

AS-BUILT CONDITION OF A PROJECT THAT IS INTERRUPTED BEFORE COMPLETION

This chapter started by listing a few reasons why a project might be closed or put on hold before its successful completion. An as-built record will be particularly important, yet most difficult to achieve, if there is any expectation that the customer will resurrect a canceled project at a later date. Interrupted projects pose great difficulties, especially if work in progress has reached the stage when materials have been bought or some components are in various stages of manufacture.

Project interruptions usually prove very expensive for the contractor. Even if all the sunk costs are recovered from the customer, it is not easy to estimate the considerable costs of ‘mothballing’ the project against the day when it might be restarted. Questions might arise about where responsibility lies for storage of partially completed drawings and hardware. Some very difficult contractual negotiations might be needed before a solution is found that is fair to both parties.

ADDITIONAL AS-BUILT RECORD REQUIREMENTS FOR FLIGHT-BASED PROJECTS

For any project that results in something that flies, or otherwise controls aircraft in flight or carries passengers, records of the as-built condition of the aircraft or aviation system are clearly vital for MRO (maintenance, repair and overhaul). There are two related issues here, which are:

1. the build state (described here);
2. traceability (described in the next section and more relevant to non-routine matters such as accident investigations).

Build Schedules

A build schedule is a list that records all the documents that define a particular project in its as-built state, listing the title, serial number and correct revision status of every drawing and specification at the time of project closure. All engineering changes should have been incorporated, so that every document is in its correct condition.

Aircraft manufacturing projects usually result in the manufacture of products that, although made from the same initial design, are likely to change as modifications are introduced between batches. These circumstances all add to the difficulty of accurate as-built definition of each product. So, for example, there could easily be an aircraft type WXY that exists in several different versions, the build state of each version possibly depending on special customer requirements or simply on the date when each individual aircraft happened to be assembled.

Clearly the individual build state of every product or component must be known for reasons of maintenance, interchangeability of parts, and to allow recall or investigation in the event of any failure in service. A familiar analogy in everyday life is the automobile manufacturer, who will introduce modifications throughout the production life of a vehicle. When any owner takes a model of that vehicle for repair or servicing, the garage will need to know the actual build status of that particular car. That is achieved by reference to the year of manufacture, more particularly, the chassis or engine serial number. The manufacturer will provide a comprehensive set of build schedules that the service engineer can access from a computer to tell exactly which components have been built into the vehicle. So it is with aircraft, but with more critical demand for detail and traceability.

Identifying Individual Units of Production

The first requirement is that each unit built (whether it is a piece of aviation equipment or a complete aircraft) should be identifiable by some mark or number which distinguishes it from its fellows. This objective is usually achieved by the allocation of batch or serial numbers. These, together with a type or part number, enable any unit to be identified positively, with no possible fear of misinterpretation.

An alternator type 10256, serial number 1023, leaves no room for doubt. If this unit is received back at the factory for servicing, repair or modification, there is no question regarding its origin, and its design status

and build content should be known. It should be possible to look at the general assembly drawing and parts list or bills of material for the generator and so discover the numbers of all the drawings and process specifications that went into its making. Now suppose that several of these alternators have been supplied to an aircraft manufacturer at different times. All are called alternator type 10256. If they have the same part number they will be interchangeable, but they are not necessarily all identical. A number of modifications might have been introduced over the period, so that different production batches contain small but significant design differences. How now can anyone tell exactly what went into the making of any one of these generators, knowing only its type number and serial number?

Thus part or assembly identification numbers, by themselves, are not always sufficient description of build status. The most common method of circumventing this problem is to compile a build schedule for each batch or products.

A build schedule comprises a list of all the drawings and specifications used in the manufacture of every unit, or batch of identical units, with the correct revision number of every drawing shown. If there is any drawing which has more than one sheet, the revision number of every sheet must be given. A separate build schedule must be compiled for every project item that is made and assembled as a single unit, but one build schedule can be used to cover a number of items where these are made as an identical batch. This is tedious but necessary. Figure 27.2 shows the typical contents of a build schedule. For convenience we have shown this as a clerical example but clearly these records would normally be held in secure digital files.

Formats such as that shown in Figure 27.2 allow all the essential build details to be recorded. Build schedules might be single-page affairs or, for larger projects, many pages assembled in hierarchical sets matching the WBS. Build schedule data were originally compiled on paper sheets, then microfiche or microfilm became popular, but build schedules are now ideally suited to computer-based systems. Build schedules are in many ways to manufacturing projects what purchase and drawing schedules are to capital construction projects.

Note that there is little point in maintaining build schedules of units with differing build standards if all the drawing information cannot be retrieved. It follows that reference files must be kept of all relevant revisions of each drawing in such cases. Put another way, if there is a drawing numbered

AR4567 that has gone through six different issues, then it must be possible to retrieve any issue of that drawing from the files. This can be achieved either by keeping every issue, or by ensuring that the latest issue contains an accurate list of the changes made for all the previous issues.

With build schedules, the comfortable premise that the latest issue of a drawing must be the correct issue is destroyed. Indeed it can happen that different revisions of the same drawing are in use at the same time when a factory is dealing with assemblies or batches of different modification status.

Modifications Made in the Field

Some modifications may be introduced into aircraft or aircraft components whilst they are in service. Such modifications need to be recorded both in maintenance log books and on the hardware itself. Labels are used for this purpose, often made as self-adhesive or riveted metal plates that can be stamped with each modification number as it is incorporated.

TRACEABILITY

Suppose that an aircraft, a Lox Aviation 123, after a normal approach, skids on a wet runway and veers off the tarmac on to grass. Safety chutes deploy and all the 310 passengers and crew escape safely, with no serious injury. There is no fire. Accident investigators discover that a failed electro-mechanical actuator caused the port brakes to lock fully on, giving the pilot no warning and no chance to avoid the accident. If this had happened on a dry runway the port tires would probably have overheated and shredded.

Lox Aviation Company is informed and all 250 operational aircraft of this type are immediately grounded pending inspection and testing of their braking systems. The faulty actuator is found to be one of a batch manufactured by Verulam Braking Systems Inc., whose products generally have a high reputation for quality and safe performance.



Figure 27.2 Essential elements of a build schedule

Lox Aviation Company now needs to know which other aircraft have been fitted with actuators from the same batch as the faulty actuator in case there was some failure in the manufacturing process at Verulam Braking Systems or some flaw in the raw materials that they used.

Traceability is the name given to this process that allows investigators to track back through assembly, component manufacture right back to raw materials to determine the source of the problem. In the Lox Aviation case, build schedules and maintenance records at the Lox Aviation assembly plant

should enable the investigators to identify all aircraft fitted with actuators from the batch that produced the faulty component. To make traceability work, it is essential that build schedule procedures are in place, as described in the previous section.

Now we need to know much more about the source of each component and the materials that went into its making. So a system of identification is needed. In practice that generally relies on the use of inspection release documents. The faulty brake actuator in this case would have been passed as fit for use by means of a final inspection release ticket, and that release ticket would itself have an identifying number and date. When Lox Aviation received each new batch of actuators into stores, secure records would have listed the quantity received, together with the relevant inspection release documents. Such batches should ideally be kept in separate bins, with the inspection release tickets attached.

Every time actuators were issued for use in the Lox Aviation assembly bay the issue would be recorded and the manufacturing records would show which batch of actuators supplied the brake actuators for each individual aircraft.

Using that information, Lox Aviation can now identify which other aircraft in service were fitted with brake actuators from that batch, and that will enable MRO establishments around the world to find and replace all those actuators as a precaution against further accidents.

Meanwhile, back at Verulam Braking Systems Inc. there is now considerable concern that one of their components has failed in use, and they in turn must be able to track back to all the smaller components and the basic raw materials used in making that suspect batch. They can do this because all those smaller components will also have their own inspection release tickets.

This is a bit like ancestor research, where census records from many years ago can be so helpful in tracing lines of descent. In aviation this traceability of course has a direct and important link to safety because it enables investigators to trace the causes of failed components or systems right back to the original source. Suppose, for example, that the brake actuator failure was caused because a batch of stainless steel rod bought in by Verulam Braking Systems from a supplier had imperfections that subsequently allowed corrosion to occur. Traceability, back through all the inspection release tickets recorded in manufacturing files would allow any other

batches of actuators made using that batch of stainless steel to be identified and replaced in all operational aircraft.

This process of traceability, based on rigid recording of inspection release information related to each unit of manufacture, is required in other industries such as some military weapons and defense systems. It demands strict adherence to procedures and the control of stock receipts and stores issues. At any time, for each stored batch of a particular component or raw material, the manufacturer needs to know and record:

- the code and description of the item;
- the supplier (if bought-in);
- the inspection release note number for the batch;
- the quantity received into stores;
- details of stores issues (with relevant job numbers);
- the quantity remaining in stock.

That is what should happen in an ideal world to allow full traceability.

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